National Park Service
U.S. Department of the Interior
Intermountain Region

Sylvan Pass Operational Risk Management Assessment

Draft Report of Results and Initial Interpretation
August 6-8, 2007 Workshop in Gardiner, Montana
Yellowstone National Park

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Introduction & Purpose

On August 6, 7 and 8, 2007, with a charge from Mike Snyder, NPS Intermountain Regional Director, 16 internal NPS and external avalanche control experts and observers undertook a very detailed, systematic review of NPS winter operations on Sylvan Pass called an Operational Risk Management Assessment (ORMA).

The process was co-led by Billy Shott, NPS Branch Chief, Law Enforcement and Ranger Activities Intermountain Region, and Chief Rodney Slade, U.S. Coast Guard. The group also had a charge to consider, as they conducted the assessment, how Sylvan Pass operations compare and contrast to NPS winter operations at Talus Slope. Figures 1 and 2 illustrate the location and avalanche paths on Sylvan Pass; Figure 3 shows photographs contrasting Talus Slope and Sylvan Pass (See Appendix C for Figures and Charts).

The primary audience for this report is Mike Snyder and Yellowstone Superintendent Suzanne Lewis, the two winter use decision-makers. With a recommendation from Suzanne Lewis and Mary Gibson Scott (Grand Teton Superintendent), Mike Snyder will sign the Record of Decision (ROD) that summarizes the Park's winter use management decision later this fall.

The important secondary audience for this report is the community of Cody and the State of Wyoming because of their intense interest in finding a way to keep Sylvan Pass open to motorized oversnow traffic (snowmobiles and snowcoaches) in the winter season.

Who Was There and Why

The Operational Risk Management Assessment took place from August 6–8, 2007. It was an open meeting with invitations sent by NPS to particular interested parties based on their expertise. Those who attended are listed below. Others who were invited but were unable to attend included Doug Abromeit of the U.S. Forest Service, Ryan Lance from the Wyoming Governor's Office, and Jamie Yount from the State of Wyoming Department of Transportation.

Table 1. ORMA Participants

Name		Role & Location	Why Present
Bachman	Don	Environmental consultant, land use policy, advocacy, snow safety, avalanche control, Bozeman, MT	Expert panelist with many years of specialized knowledge of corridor avalanche forecasting and control operations. Currently consulting for Glacier Park regarding avalanche mitigation issues connected to Burlington Northern operations in Glacier Park.
Birkeland	Karl	Snow Scientist, U.S. Forest Service National Avalanche Center, Bozeman, MT	Expert panelist with many years of specialized knowledge and experience in avalanche forecasting and avalanche control operations. Specialized experience on the Gallatin National Forest, adjacent to the Park.
Campbell	Colin	NPS Deputy Superintendent, Yellowstone National Park	Observer.
Chandler	Nedra	Cadence, Helena, MT	Independent facilitator for agency and public participation in winter use planning and decision making. Has no stake in the outcome(s)—sole role is to facilitate communications.
Comey	Bob	Geologist and avalanche specialist, Jackson, WY	Expert panelist. Wrote report: Avalanche Hazard Assessment and Mitigation Report: Sylvan Pass, Yellowstone National Park for Suzanne Lewis, March 2007. Director of the Bridger-Teton Avalanche Center. Lead avalanche forecaster for the Jackson Hole Mountain Resort. Has expertise in avalanche assessment and mitigation in North America, Switzerland and New Zealand including a long time familiarity with the operations of the Sylvan Pass avalanche program.
French	Tim	Park County Commission, Cody, WY	Observer. Elected commissioner from Cody and winter use EIS cooperating agency representative for Park County. Has key interest in maximizing “openness” of Sylvan Pass in the winter, and continued acceptability of oversnow vehicles using the east entrance to keep growing Cody’s economic and community vitality.
Keator	Michael	Lake District Ranger, Yellowstone National Park (NP)	Expert panelist. 15+ years of specialized knowledge of Sylvan operations—supervises east side operations.
Meyer	Ken	Safety Manager Yellowstone NP.	Expert panelist. Twelve years of safety and risk management experience in private industry and government including OSHA.
Obernesser	Rick	Chief Ranger, Yellowstone NP	Observer.
Pochelon	Remy	Ecosystem Research Group, Missoula, MT, contractor to the State of Wyoming Office of the Governor, Cheyenne, WY	Wyoming State Governors Office Consultant Observer.
Sacklin	John	National Park Service, Yellowstone National Park Management Assistant to Superintendent Lewis	Observer. Winter use team leader since mid-90s.
Sefton	Bruce	Maintenance Supervisor, Lake District. Yellowstone NP	Expert operations panelist. Supervisor, road operations in Lake District and Sylvan Pass. 15+ years of specialized knowledge of Sylvan operations.

Name		Role & Location	Why Present
Shott	Billy	Chief, Branch of Law Enforcement and Ranger Activities Intermountain Region	Operational Risk Management Leader invited by NPS Intermountain Regional Director Mike Snyder and Yellowstone Superintendent Suzanne Lewis to lead the objective, collaborative look at risk to employees and visitors related to Sylvan Pass operations.
Slade	Rodney	Chief, U.S. Coast Guard	Operational Risk Management Leader brought in to provide an outside expert perspective on ORM process and results from a sister federal agency that, unlike NPS, has been doing this type of assessment for the past 20 years.
Swanke	Steve	Deputy Chief Ranger, Yellowstone NP	Expert panelist. Supervisor. Manages operations throughout the park and was Lake District Ranger and supervised Sylvan Pass Operations.
Swanke	Denice	Outdoor Recreation Planner	Observer. NPS winter use team member, one of the co-authors of winter use EIS document.

Selected Context—Past and Present

Below is a chronology that highlights some of the key events since 1932 that have helped shape the context for winter use decision-making in general and Sylvan Pass winter operations specifically.

This chronology was adapted from a more detailed version, Appendix B: History and Timeline, of the March 2007 Winter Use Plans Draft Environmental Impact Statement for Yellowstone and Grand Teton Parks and John D. Rockefeller, Jr. Memorial Parkway.

Table 2. Winter Use Chronology

Date	Description
1932-1989	In 1932, interested people in Cody requested that the NPS plow roads into Yellowstone to allow year-round access. Park authorities turned down the requests citing poor roads, severe winter conditions, un-winterized buildings, and lack of rotary plows. In 1938, NPS began plowing Mammoth to Cooke City year-round. Two years later, Cody asked again to look at feasibility of plowing Park roads year-round and the Park declined again. Requests for Park plowing continued to roll in over the next decade from Cody and other local communities. With additional concerns about wildlife getting trapped in road corridors with snow piled high on the roadsides, on the NPS continued to turn down such requests, while soon accommodating a new form of winter tourism, oversnow motorized vehicles. In 1955 several West Yellowstone people began offering the first snow coach tours of Yellowstone and several thousand people tried it the next several winters. In 1956, local communities again asked the agency to consider plowing park roads. In response, an NPS committee concluded it was feasible but not practical due to poor roads, severe weather, estimates of low traffic volumes, and cost of necessary developments and road improvements. In 1963 the first modern snowmobiles entered Yellowstone. In 1972 President Nixon issued Executive Order 11644, establishing a federal policy on off-road vehicle use in relation to resource issues. Yellowstone's Superintendent Jack Anderson responded by designating all the park's interior roads for snowmobile use. In 1973, NPS began conducting avalanche control operations on Sylvan Pass to provide a safe travel corridor for visitors. By 1981, winter use had increased to 105,000 visitors annually (parkwide). In the 1980s the NPS closed Dunraven Pass due to avalanche concerns there, and current management is backcountry use.
1989-1996	Winter use visitation continued to increase. Regarding Sylvan Pass operations during this period, Ranger Bob Mahn died in a 1994 accident while on patrol en route to Sylvan Pass to assess the avalanche danger there.
1997-2005	See details in the EIS Appendix to review the succession of planning and lawsuits regarding winter use during this period. Regarding the Sylvan Pass aspects of the analyses, note that both the first EIS and Supplemental EIS examined avalanche control at Sylvan Pass, acknowledging that there was considerable risk in operating an avalanche control program there. Also in 2001 and 2004 respectively, the Occupational Safety and Health Administration (*Sylvan Pass: Yellowstone National Park*, OSHA, 2001) and the State of Montana (*Potential Environmental and Safety Impacts Associated with the Use of Ordnance for Avalanche Control at Sylvan Pass, Yellowstone National Park, Wyoming*) identified hazards related to job tasks in Sylvan Pass avalanche control program.
June 2005	Scoping began on the new winter use EIS.
Fall 2005	Superintendent Lewis and several winter use team members met with Cody interests to discuss which scenarios would be modeled—this was the first time the possibility of closing Sylvan to oversnow vehicles was raised by Parks in the current EIS process.
January 2006	NPS and 10 cooperating agency representatives (the three states, five counties, EPA, the Forest Service and NPS) signed the information-sharing Memorandum of Understanding (MOU) for this (4th) EIS process.

Date	Description
March/April 2006	NPS held information-sharing meetings in Bozeman, Montana and Jackson, Wyoming to roll out preliminary scenarios for managing recreational winter use in the parks. These open meetings invited agencies and public participants together to look at six scenarios for managing winter use in the parks. Several of these scenarios contemplated closing Sylvan Pass to motorized oversnow vehicle use. Cooperating agencies met in Idaho Falls to review what NPS had heard from public and audience commenters.
Summer 2006	Superintendent Suzanne Lewis visited Cody interests and let them know more about what she was learning about risks inherent in avalanche control on Sylvan Pass in anticipation of continued study of those alternatives that would cease avalanche control and grooming on the pass during winter.
November 2006	NPS released a preliminary review draft of the Draft Environmental Impact Statement for Cooperating Agency review. The agency preferred alternative called for closing Sylvan Pass to motorized travel beginning in 2008-09 while leaving it open for ski and snowshoe access (and skier/snowshoe drop off) to a point about six miles west of the entrance. Two of the other five alternatives also called for the pass to be closed to motorized vehicles.
December 2006	Cooperating agencies met in Cody for a cooperators meeting and information fair to explain the reasoning behind the approaches shown in the preliminary draft. Now that the possibility of ceasing avalanche control on the pass and closing it to oversnow vehicle use had become much more real, State of Wyoming and Park County interests stated their strong interest that the east entrance remain open for snowmobile and snowcoach travel. They noted how much they felt the community and economic health of Cody and the broader city region depended on that access for motorized travel in the winter. NPS committed to developing options for keeping the pass open, but did not commit to changing course on the preferred alternative. In the Cody area, a grassroots community group called *Shut Out of Yellowstone* formed, for the purpose of working to keep Sylvan Pass open to motorized oversnow vehicle use in the winter.
January 2007	*Shut Out of Yellowstone* hosted a community forum with about 500 participants and Superintendent Lewis among the invited panelists to discuss the Sylvan Pass aspects of the preliminary Draft EIS (the official Draft EIS was not yet out for formal public review).
Spring 2007	Superintendent Lewis continued to meet with Cody-based interests to seek clarity and a common base of understanding about the Park's approach to risk management on Sylvan Pass. While Cody interests expressed appreciation for the working relationship they do have with the Park, they reported surprise about ceasing avalanche control in the preferred alternative. Other issues connected to Cody-Park communications were raised again about internal and external communications about weather and conditions, and when the east gate was open or closed in the winter. Cody, in their gateway community role, felt lower numbers entering the east gate was a self-fulfilling prophecy related to a pattern of ratcheting down the winter opportunities at the east gate over time. Participants also continually emphasized they would value stability of winter use park policy so Cody can better plan for and build their socioeconomic opportunities related to their proximity to the Park. The winter use team emphasized that no decision was yet made, that because of risk there is/was limited room to move, but that they were willing to keep listening and exploring options until the time at which they have to have a decision and rule in place in order to have a winter season in the parks. NPS emphasized their significant investments on east side road and Canyon visitor center highlighting NPS is not "trying to shut the east gate down." Superintendent Lewis explained differences between the NPS approach to risks and hazards in front country and non-maintained back country—especially as it relates to the howitzer gun (for avalanche control), helicopter-discharged avalanches, and trying to keep the road open in the winter. She emphasized NPS attention to risks regarding avalanche control on Sylvan is not new and not an expedient way to justify the preferred alternative.

Date	Description
March 2007	The Draft Environmental Impact Statement (DEIS) was released for the 60-day public comment period, with the preferred alternative continuing to include the proposal to cease avalanche control activities on Sylvan and close it to motorized oversnow vehicle use in the winter season.
May 2007	NPS convened four public comment meetings for the DEIS in Cody, Wyoming; West Yellowstone, Montana; St. Paul, Minnesota; and Lakewood, Colorado. Wyoming Senators Thomas and Enzi and Representative Barbara Cubin delivered a letter to the winter use team emphasizing their primary concern with the Draft EIS was the possible closure of the East Entrance (to motorized oversnow vehicles in the winter). They urged the NPS to reconsider their preferred alternative.
June 2007	Regional Director Mike Snyder and Superintendent Suzanne Lewis met with Cody interests to discuss the range of concerns. One result of that meeting was Snyder's request for an Operational Risk Management Assessment to be conducted to objectively assess the hazards and risks associated with techniques currently used by NPS staff and to review potential strategies that could be used by NPS staff to control avalanche threats on Sylvan Pass. The charge was to use process and procedures of *Operational Risk Management (ORM)* developed by the United States Coast Guard to systematically and methodically assess each mitigation option and quantify the risk exposure to both employees and visitors.
August 2007	Operational Risk Management Assessment conducted with a panel of seven NPS internal and external/independent avalanche experts with observers of the work from the Park and Cody and the State of Wyoming.
Now: Next Steps	The winter use team plans to publish the Final EIS this fall (no further public comment is called for under the National Environmental Policy Act at this stage). The results of the ORMA will be integrated into the avalanche control appendices of the EIS, and help inform NPS decision makers as they finalize the Record of Decision (ROD) and the Rule to implement the ROD. Both will be signed by Intermountain Regional Director Mike Snyder with recommendations from the two park superintendents, Suzanne Lewis and Mary Gibson Scott. In any case, whether the NPS decision is to go forward with some version of the current preferred alternative or to modify the preferred alternative regarding Sylvan Pass winter operations, no closure to oversnow vehicles will occur in the 2007-08 season.

Additional Historical Considerations of Visitor and Employee Safety on Sylvan Pass

Yellowstone has been conducting avalanche control operations at Sylvan Pass since 1973. The 2000 EIS, the 2003 Supplemental Environmental Impact Statement (SEIS), and the Temporary Winter Use Environmental Assessment (EA) of 2004 acknowledged there is a considerable risk in operating an avalanche control program at Sylvan Pass. The 2000 EIS considered closing Sylvan Pass. The NPS used to allow motorized oversnow travel between Canyon and Tower Fall over Dunraven Pass in Yellowstone. Growing concerns over avalanche danger prompted the park to close Dunraven to snowmobiles in the 1980s.

Yellowstone stepped up its commitment to visitor and employee safety in recent years in all facets of park operations. Outside agencies including the Occupational Safety and Health Administration (2001) and the State of Montana (2004) have looked at the risk of avalanche control on Sylvan Pass.

During this current winter use planning effort, NPS conducted new evaluations on a variety of options to manage avalanches and improve safety. The preferred alternative in the DEIS that came out in 2007 would close Sylvan Pass to all motorized oversnow travel because of unacceptable risks to visitor and employee safety.

Trained, experienced NPS rangers run the avalanche control program at Sylvan Pass. The program has been successful to date preventing “negative avalanche-human contact,[1]” yet, because of the magnitude and complexity of Sylvan Pass it is understood as dangerous work[2]. One person has died as a result of these winter operations on Sylvan. Ranger Bob Mahn died in a 1994 accident while on patrol on Sylvan to assess the avalanche danger on the pass. Over the years there have been several instances when park employees or visitors had close calls or near misses with avalanche mitigation-associated operations.

During historic use, the peak number of people who traveled through Sylvan Pass was less than 4,440 people during the 2001–2002 winter season. That’s about the same number of visitors that travel through Sylvan Pass on a single peak day in the summer.

(Original source of text adapted above: NPS Winter Use Plan and EIS Yellowstone and Grand Teton National Parks John D. Rockefeller, Jr., Memorial Parkway Newsletter March 2007 and descriptive comments offered by expert panelists in August 2007.)

[1] This was the short-hand phrase the expert panelists kept in mind as the goal as they conducted the assessment August 6-8, 2007.
[2] The east entrance road crosses 20 avalanche paths through Sylvan Pass (see Figure 2 aerial photo). Rangers must travel through four uncontrolled avalanche zones, to reach the howitzer, which has been used for avalanche control. In addition, sometimes the munitions used for avalanche control don’t explode, leaving hazardous unexploded ordnance that can later reach the road corridor where they pose a threat to visitors and employees. For these reasons, the Park began to use helicopters for avalanche control starting in the winter of 2004-2005, and then switched completely to the use of helicopters for avalanche control during the winter of 2006-2007. Rangers lack a weather station that would allow consistent forecasting. In addition they contend with extreme conditions, including for example, arctic cold temperatures, extreme tendency to wind loading, on a “moving” mountain of unconsolidated materials under the snow (unlike Talus Slope). Rangers do this to keep the pass open for oversnow vehicle, recreational use (not interstate commerce). The expert panelists knew of no other place where NPS rangers are doing this kind of avalanche control.

III. ORMA Process & Lists From Expert Panelists

This segment contains the ORM instructional materials and group work products from the three-day workshop itself (August 6–8, 2007). It is cataloged here to provide a brief record of the steps the group followed—how they moved through each Operational Risk Management Assessment task. The material is divided into two main parts; foundations (for the work), and products (of the group). The subsections below roughly follow the order in which the group moved through each part.

Foundations

The group began with self-introductions and confirmed the substantive, procedural, and relational results they were seeking[3], as well as the workshop objectives.

Workshop Objectives

- **Demonstrate:** Provide a thorough understanding to the Operational Risk Management (ORM) process.
  - Participants will efficiently be able to use the process and apply the principles in their role of providing objective expertise.
  - Observers will understand the systematic and procedural methods involved in assessing risk profiles of avalanche control activities.
- **Do:** Use the ORM process to complete a systematic and methodical review and assessment.
  - Gather meaningful data specific to Sylvan Pass without regard to subjective interferences.
  - Provide a detailed report of employee and public safety risks associated with avalanche control operation decisions on Sylvan Pass.

Background on ORM

U.S. Coast Guard Chief Rodney Slade and Law Enforcement Branch Chief Billy Shott described the origins, benefits, and process of ORM. The U.S. Coast Guard developed it approximately 20 years ago

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[3] *Substantive Outcomes Desired*

1) Systematic, methodical definition of: Sylvan pass avalanche control mission, identify hazards, assess risk, identify options, evaluate risk versus gain ratio.
2) Operational Risk Management Report delivered by Billy Shott to Mike Snyder and Suzanne Lewis by end of August, 2007.

Procedural Outcomes Desired

3) Assist park managers toward informed risk decision(s) regarding avalanche control activities for Sylvan Pass.
4) Continued clarity and honesty about who has what kind of influence in the winter use decision and implementation steps and schedule and post/share results with anyone interested.

Relational Outcomes Desired

5) Expert panelists fully engage as raters to get to the substantive results above.
6) All in the room continue to invest in collaborative working relationships for the long term.

after a major mishap, which resulted in the loss of lives (the Sea King rescue). The National Transportation Safety Board charged the Coast Guard with making system changes and ORM was born. Chief Rodney Slade pointed out that one of the reasons the Coast Guard shone in the Hurricane Katrina situation is because of ORM.

Billy Shott further described how and where the National Park Service is making it a priority to integrate ORM into National Park Service safety culture (where culture can be defined as “how we do things around here”). The Intermountain Region is implementing ORM in all aspects of their ranger activities branch and is influencing the way the agency functions from the inside out. A key feature of ORM:

Operational Risk Management does NOT tell you what to do, it gives you an accurate assessment of ALL risks and asks the question: “What is acceptable to you?”

Four Core Principles

Four core principles of ORM that facilitate the critical thinking necessary to objectively complete this assessment:

1. Accept no unnecessary risk
2. Accept risk when benefits outweigh the cost
3. Anticipate and manage risk by planning
4. Make risk decisions at the right level.

Seven Key Steps of ORM

The group reviewed the seven key steps of ORM:

1. Define mission
2. Identify hazards
3. Assess risks
4. Identify Options
5. Evaluate Risk vs. Gain
6. Execute Decisions
7. Supervise (watch for changes).

It was noted that we would have to develop a “mission” definition that could potentially apply to any avalanche control option conceived.

Green Amber Red—The “GAR”

The group was instructed on use of the “GAR”—Something Chief Slade called a “living, breathing animal”—a fluid tool, not a static exercise. Users can use it to continually adjust operations to minimize risk and maximize gains. GAR stands for Green, Amber, Red as depicted in the simple rating scale below. The GAR is a model and tool that is ideally used to evaluate an individual rotation of a field operation and is also used to assess operations programmatically. The numbers that correlate with the colors serve as a guideline measurement and should not be considered a steadfast definition of risk or hazard. ORM recognizes that different organizations and workgroups within organizations have different levels of acceptable risk. (i.e. the training division of an organization typically has a lower tolerance for risk than the operational division, the military typically has a higher tolerance of risk than a civilian organization, the military has a higher tolerance of risk when at war than during peaceful periods). It is up to an organization's leadership to define what levels of risk are appropriate.

Table 3. GAR Scale

RED (High Risk)	**80**
AMBER (Caution)	**60**
GREEN (Low Risk)	**35**
	0

Risk Calculation Worksheets

The group was further instructed in the use of the risk calculation worksheets they would be using to rate activities or options for avalanche control. The worksheet looks like this one below, and expert panelists rate them on a scale of 1 to 10, with 10 being most risky. Panelists do this individually, but always check each other's assumptions and learn more through dialogue. For example, the question, "who put more than 6 on supervision?" leads to discussion, in which participants may or may not reconsider their rating in light of more or new information from peers or other panelists.

Table 4. Sample Risk Calculation Worksheet

SUPERVISION			
PLANNING			
CONTINGENCY RESOURCES			
COMMUNICATION			
TEAM SELECTION			
TEAM FITNESS			
ENVIRONMENT			
INCIDENT COMPLEXITY			
TOTAL			

Working Definitions of GAR Elements

The working definitions of these categories were important to review as a group so that all panelists were operating from the same framework. The group reviewed and discussed each in turn.

Supervision

Supervisory Control should consider how qualified the supervisor is and is supervision taking place. Even if a team member is qualified to perform a task, supervision acts as a control to further minimize risk. This may simply be someone checking what is being done to ensure it is correct. The higher the risk, the more the supervisor needs to be focused on observing and checking. A supervisor who is actively involved in a task (doing something) can be easily distracted and should not be considered an effective safety observer in moderate to high-risk situations.

Planning

Planning and preparation should consider how much information you have, how clear it is, and how much time you have to plan the incident or evaluate the situation. Planning the evolution includes the use of pre-defined plans and onsite incident plans.

Contingency Resources

Contingency resources should include what pre-defined resources will be called in an overwhelming incident. Items to consider include:

- Who are you going to call?
- Are they available?
- What is their capability for the incident?

Communications

Communications needs to ensure clear and accurate sending and acknowledging of information, instructions, and commands; and providing useful feedback. Items to consider are not only interpersonal communications but also physical communication equipment.

Team Selection

Team Selection should consider the qualifications and experience level of the individuals used for the specific incident or operation. Individuals may need to be replaced during the incident or in the operation. The same concerns apply to the relief teams.

Team Fitness

Team Fitness should consider the physical and mental state of the team. This is a function of the amount and quality of rest a team member has had. Quality of rest should consider conditions slept in, potential sleep length, and any interruptions. Fatigue normally becomes a factor after 18 hours without rest; however, lack of quality sleep builds a deficit that worsens the affects of fatigue. Other factors to consider are physical preparedness and personal life factors that may impede the outcome of the incident.

Environmental

Environment should consider factors affecting personnel performance and factors affecting the performance of equipment, vehicles, vessels, or aircraft. This includes, but is not limited to, time of day, temperature, humidity, precipitation, elevation, isolation, vertical exposure, proximity to aerial/navigational hazards and other exposures (e.g. oxygen deficiency, toxic chemicals, and/or injury from falls and sharp objects).

Incident Complexity

Incident complexity should consider both the required time and the situation. The longer exposed to a hazard, the greater the risks. Factors considered include how long the environmental conditions will remain stable and the complexity of the work.

Then the group began making a joint list of all the options they could think of to achieve the mission, stated as simply as possible "to keep snow off people" on Sylvan Pass.

The options were named and re-named and defined a few times during the three days, but the end list and what the group meant by each is described below. These are in alphabetical order, but there is a second list below Table 5 that shows the group's sorting and sifting on day 2, moving from most to least effective.

Background on Severity, Probability and Exposure

The panel was introduced to the Severity-Probability-Exposure (SPE) risk model where a measurement of Risk = Severity x Probability x Exposure. This is a model used to take a closer look at specific operations and is helpful to consider when planning ongoing operations. The definitions of the components are:

- **Severity:** potential loss or consequences of a mishap (Risk Control—Protective devices, engineering controls, and personal protective equipment are used to control Severity.)
- **Probability:** The likelihood that given exposure, the projected consequences will occur. (Risk Control- Training, awareness, attitude change, etc.)
- **Exposure:** The amount of time, number of cycles, number of people involved, and/or amount of equipment involved (reducing the number of people involved, the number of events, cycles, evolutions, etc.).

Table 5. SPE Worksheet

Values	Risk Level	Action
80-100	Very High	Discontinue
60-79	High	Immediate Correction
40-59	Substantial	Correction Required
20-39	Possible	Attention Needed
1-19	Slight	Possibly Acceptable

After computing the risk levels for each hazard identified, those hazards can be rank ordered from the highest to the lowest risk. This allows you to focus on the areas of most concern first under conditions of limited resources.

Universal Risk Considerations

The group was exposed to the concept of "Universal Risk Considerations" (e.g., things such as injury, occupational illness or death; equipment damage, fiscal resource; adverse or positive public impacts; reduced morale; adverse administrative and/or disciplinary actions). It was noted that many of these considerations will be applied to this process; however, the priority of this workgroup was to focus on the risk associated to employees and public. (Further discussion of universal risk considerations occurs later in this report).

Products of this Group

Upon completion of the ORM orientation it was re-stated that this group would conduct ORM steps 1-5 in the 3 days they have. The group took the foundations from the morning's training in ORM and began doing the assessment itself.

Mission: Keep Snow Off People

The group accepted the working description of the mission: "**keep snow off people**" or "**avoid negative avalanche-human contact**."

It was discussed that any option is potentially feasible to achieve that mission—an open mind is part of the process, keeping the steps honest and methodical, rather than value-laden and assuming at this stage. Also, the group agreed not to discuss financial costs of options until the very end of day 3.

Options to Achieve the Mission

The basis of the review is to evaluate operational risk in any and all potential avalanche control options. The group was tasked with identifying avalanche control options that could be applied to Sylvan Pass. Following is the list of options generated with a brief description.

These are in alphabetical order only.

Table 6. Avalanche Control Options

Option	Description/Working Definition
Access	Travel during winter conditions usually by snowmobile and often as a single person from the NPS facilities at Lake Village (21 miles) and the East Entrance (7 miles) to Sylvan Pass for the purposes of conducting avalanche hazard assessment and mitigation efforts.
Artillery	Military weapons such as a Howitzer, Recoilless Rifle or Battle Tank that shoot high velocity explosive projectiles are used to test snow stability and trigger avalanches in a controlled environment.
Avalauncher/LOCAT	Non-military devices that use compressed gas to shoot low velocity explosive projectiles are used to test snow stability and trigger avalanches in a controlled environment.
Backcountry Standards	Pass is left open without active mitigation techniques. NPS conducts general forecasting of avalanche hazards. The public is left to assess the hazard and act accordingly on their own.
Berms, Deflectors, Catchment Basins	Engineered structures that retard the forward advance of avalanches or deflect the flow of avalanches away from structures or areas or concern are constructed.
Closure + Helicopter Hybrid	The pass closes in the fall when the avalanche paths of concern begin to accumulate snow and remains closed until designated date in early May. Helicopter deployed explosives would be used to assess and mitigate the avalanche hazard for pre-opening snow removal efforts and to address avalanche hazards that occur after the road is opened.
Fixed Gas + Helicopter Hybrid	Explosions originating from fixed installations located near the avalanche starting zones and from hand charges dropped from a helicopter are used to test snow stability and trigger avalanches in a controlled environment.
Fixed Gas Systems	Mixtures of explosive gases are remotely detonated from fixtures installed near the avalanche starting zones in an effort to test the stability of the snow and release avalanches in a controlled environment.
Full Forecasting	The use of experienced personnel and resources including specialized remote automated weather stations to monitor conditions, assess the avalanche hazard and open the pass during the winter season when conditions are safe with respect to potential impacts from avalanches. There would be no use of explosives to test snow stability or trigger avalanches.
Hand Charges	Workers on skis deploy explosive hand charges into avalanche starting zones to test snow stability and trigger avalanches in a controlled environment.
Helicopter	Helicopters are used to drop explosives into avalanche starting zones to test snow stability and trigger avalanches in a controlled environment
Helicopter + Howitzer Hybrid	Military weapons and a helicopter are used to deploy explosive charges into avalanche starting zones to test snow stability and trigger avalanches in a controlled environment.
Howitzer + Access Mitigation Hybrid	Military weapons are used to test snow stability and trigger avalanches in a controlled environment in the majority of the avalanche paths. Alternative methods (trolleys, fixed gas system, hand charge routes, sheds or start zone support structures) are used to mitigate the hazard in the avalanche paths that impact the approach to the gun mount.
Snow Sails	Specially designed sails or wind fences are installed perpendicular to elevation contours along the windward side of avalanche starting zones. These structures

Option	Description/Working Definition
	can disrupt the pattern of snow deposition in avalanche starting zones and may decrease the frequency of avalanche occurrences.
Support Structures in Start Zones	Engineered structures (specialized fencing in multiple parallel lines along elevation contours) are permanently installed in avalanche stating zones. These structures keep unstable snow from moving downhill and causing an avalanche.
Total Closure (“Snowflake to snowflake” when the first falls and last melts.)	No access allowed when there is snow in the avalanche paths that can potentially impact the East Entrance Road on Sylvan Pass.
Trolleys	Explosive charges are delivered to avalanche starting zones via a system of permanently installed cable and towers in an effort to test snow stability and trigger avalanches in a controlled environment.
Tunnel/Shed	The East Entrance Road would be re-routed though a tunnel to avoid the area of avalanche hazard on Sylvan Pass. A snow shed would be built over the road in the area on Sylvan Pass that is threatened by snow avalanches. Avalanches would flow over the road on top of this protective shed with no impacts to travelers.
Window Closure (Similar to “total closure” above but reduces the window of time the pass is closed in each shoulder season fall and spring.)	Employees with avalanche experience and local knowledge monitor conditions with the objective of closing the pass when conditions dictate in the fall and reopen it when conditions permit in the spring.

Very, Middle and Least Effective

Then the group began to sort and group the options into the three general categories of very, middle and least effective for Sylvan Pass. As part of this discussion they also worked to compare and contrast effectiveness of measures on Sylvan versus Talus Slope (see the *Talus Slope Comparisons* section below for a summary of the Sylvan versus Talus Slope discussion).

Very Effective

- Total closure
- Tunnel/snowshed
- Re-route road
- Snow fencing (supporting structures in starting zone)

Middle Effective

- Closures 2, 3, 4, 5
- Helicopter
- Artillery
- Fixed gas system—Gazex/Avalhex
- Hand charges

- Pre-placed explosive charges
- Avalguard
- Trolleys

Least Effective

- Berms
- Deflectors
- Catchment basins
- Snow sails
- Avalauncher/LOCAT
- Heli Avalhex

Of special note this initial categorization of effectiveness was significantly changed by the panel during the final day of the review when they were asked to rate numerically effectiveness of the options (see risk vs. gain scores, Appendix B). One potential reason for this is that the panel better understood the current operation and resources as it relates to the specific demands of Sylvan Pass (Refer to Appendix B, risk vs. Gain data for final group concurrence on effectiveness).

Unique or Notable Qualities of Sylvan Pass

It was important for everyone to know the specific attributes of Sylvan Pass so that: a) all potential hazards could be identified, b) a better understanding of how individual options could be applied, and c) to better compare it to other road corridor areas that require avalanche control work. The panel identified the following unique or notable qualities of Sylvan Pass.

Table 7. Unique /Notable Qualities of Sylvan Pass

Notable Quality	Notes/comments from Panelists
Access	Can't control howitzer from outside the area with current technology
Vulnerability to the platform	From cornices, rockfall, natural hazards
"Long return" avalanche could roar down south face of Hoyt	
Cold climate—extreme artic conditions	
Start zones within proposed or recommended or existing Wilderness	(Note: this may not be all that unique—e.g., Glacier National Park, Cascade National Park, Mt. Rainer, and Little Cottonwood Canyon among other locations have this quality.
Start zones are similar in aspect, slope and elevation. Spatially too, results of avalanches are similar and contained.	Note that the egress to the gun mount is different. This area of start zones constitutes a "nice little scary, but contained, package…"
Doing avalanche control for recreational use	Sylvan is the only discretionary use of explosives in a corridor like this (i.e., not a ski area—this is a road corridor for recreational use, not interstate commerce.)
Uniquely controversial	Context for winter use decision making is controversial with litigation, "the world's first National Park," intensely interested gateway communities, and so on.
Intermittent control—"where else do we have rangers doing this kind of avalanche control?"	With regard to avalanche risk. Our full attention isn't there. Consistent attention not possible. Not up to "industry practices."
Type of traffic	Skier, oversnow vehicle or bicycle is going to be in slide path longer.
Guided situation	NPS has the opportunity to use those guides to help decrease the risk with respect to hazard. NPS can use their entrance stations to give education and information materials to visitors to help. NPS also has control over administrative travel.
Availability of others—contingency resources	
Logistics are unique: timing, distance, our targets change, and we have to maintain with a groomer. We also have to heat the barrel on the howitzer.	e.g., how we get to the fixed mount gun with OSV—snowmobile only. This is unique. It's also slower and less environmentally friendly. This is a 20 miles distance—it's remote. Also: groomer takes 3 hours to get there while others heat the barrel.
Federal Highway Administration says Sylvan is unique with its unconsolidated material	"No bedrock, the mountain is moving…"
Interaction of excessive number of unexploded ordnances in the vicinity with mudflow	Group's note to itself: duds will show up as hazard, but the additional situation of unconsolidated material makes it notable here.
Wind	Lots of wind loading. Have to use precision targeting with our explosives.

Notable Quality	Notes/comments from Panelists
Unique Equipment	Regarding the howitzer, we have a 102; everyone else has 101s. Requires relatively warm environment to function.
Proximity of road to slope	Road is directly below slope of descent. There is no room to relocate road within corridor to avoid this.
Angle of fire—projectile	Very difficult to precision hit extreme sides of avalanche slopes. Effectiveness of “hit or impact” decreases.

Talus Slope Comparisons

After the group identified unique or notable qualities about Sylvan Pass several qualities of Talus slope were noted to compare and contrast. Abbreviated comments from panel discussion include:

- Big “magnitude and duration” differences between Sylvan and Talus.
- Basic description is Talus has about a 3-400 hundred foot run on it and is not extremely wind loaded (as Sylvan is)
- Standard deposition (unlike the loose, unconsolidated material on Sylvan)
- Big boulder fields provide good anchor points on Talus
- Talus Subjected to 1988 fires. All that growth of “doghair” lodgepole also inhibits likelihood of slide.
- Slides hit the road below Talus maybe once every 10 or 15 years, leaving only about 2 feet of snow on the road. You’d have to be lying down to get covered, or have a heavy pack on and fall...
- There is never a day in the winter the Talus slope isn’t ski-able (this could be one good way to control it).
- Talus is a non-issue based on its history and size.
- Talus is a place where if you put up the sign that says, “don’t stop” that’s good.
- Berms and catchment basins seen as least effective on Sylvan may be most effective on Talus.
- Forecasting is so much more effective for Talus because the physical attributes are so different and magnitude of the events so much less at Talus.
- Complexity of Sylvan is huge next to Talus (which is not complex).
- On Sylvan, hazard usually begins in November where on Talus there may not be hazard until January or even no hazard the entire season.

Hazards

Then the group identified hazards associated with access (to the site) as well as those related to avalanche mitigation-related tasks. The panel noted there are hazards associated with the 20 mile approach by snowmobile to the avalanche zones from Lake, and the approximately 6-mile approach from the east side to Brown Drifts, so there are hazards getting to the site to control the avalanches, and hazards once there.

Table 8. Hazards Associated with Site Access

Category/Type of Hazard	Notes/Comments from Panelists
Snowmobile accident	Ergonomics of driving snowmobile is hazardous. Cold, injuries, driving off the road or other accident.
Collision	Hit stationary object.
Ungroomed road	
Stuck snowmobile	
Visibility	
Extreme conditions	Potential for sluff to come down on road.
Mechanical failure	Then there's the hazard of exposure to weather when you get a failure.
Places where there is no guard rail coming from east side	More of a hazard coming from east side
Low staffing, dark	Staffing comes from Lake 7 a.m. and East can't leave until it's light (7 a.m.). Now no groomers up there at night. By the time you get to Pahaska teepee, you are returning under the slide paths at dark. East road guard people check it every day prior to opening, team of two travels up from east, last year one came from east, one from Lake, and they would pass below the paths. 17 employees have been killed in history of Yellowstone Park, more than a handful in the winter. About 6 property damage or personal injury accidents with snowmobiles a year. Snowmobiling is inherently unsafe. We chose in the 1960s to do it, now we're trying to make it work.

Because of the significant hazards associated with just accessing the staging area of Sylvan Pass it was identified that "access" should be considered its own independent activity. There is further discussion of "access" later in this report.

GAR Scores for 19 Options From Panelists

The group individually scored, discussed, and assessed each of the 19 options in turn. The raw scores off these worksheets are compiled for reference in Appendix A of this report. Each panelist had their own worksheet to score the eight operational elements on the GAR (see the *Foundations* section above).

Severity Probability Exposure Assessment

The group utilized the severity, probability and exposure (SPE) model (see the *Foundations* section above) of a few of the options as examples. Using SPE worksheets, they individually assessed the SPE for the options, which have been used most recently (using the helicopter and howitzer) as well as conducting a SPE as a comparison between Talus Slope and Sylvan Pass.

At the end of Day 3, the group put a large wall chart up on the wall and built the following matrix to jointly assess factual gains. For this exercise the group of experts invited the observers to participate in the discussion of the rating scales, effectiveness, pass "openness and closedness", resources, and costs.

Quantifying "Factual" Gain

One of the final exercises conducted was applying a numeric score (0 to 6) to those "consequences or outcomes" of each option which are based in fact and could be considered a gain. This information can then be compared to risk profile scores as a way to begin assessing the risk vs. gain of each option. Those outcomes that this panel was able to asses include: 1) Effectiveness of option to meet objective of "avoiding negative human/snow contact," 2) Amount Sylvan Pass remains open, 3) Amount of impact to surrounding environment, and 4) general cost of implementing option. See Appendix B for a compilation of these scores.

Final Group Discussion

The workshop concluded with a review and discussion of the raw data and those findings easily identified. Some inconsistencies were noted (and later noted in this report) but it was generally felt that the assessments appeared accurate and realistic. Other notable points shared by the panelists include:

Group Notes Regarding Forecasting

The group assumed a weather station would lower risk. Forecasting, dedicated personnel, and local knowledge/experience would all lower risk.

Group Notes Regarding Spring Snow

Forecasting is more difficult with wet slabs and alters the effectiveness of any option. This is important to know when considering options that either do or do not include other "snow moving" techniques, (i.e. artillery, fixed gas, etc.) or options that require clearing Sylvan Pass in the spring.

Softening of a loaded snow slab is very poorly understood even by the avalanche control community. The implications are significant and not intuitive to normal thinking when assessing risk in avalanche control activities. All mitigation tools are much less effective in wet slab situation. Forecasting when wet snow conditions exist is more difficult, and hazards are more likely to change day to day and even hour to hour due to temperatures, exposure, moisture content, etc. Adding the difficulties of forecasting to the expected timelines of opening the pass compounds the chance of potential avalanche accidents.

It was generally thought by the panel that opening and closing the pass with only forecasting as a tool was hazardous unless extremely conservative. Further, the group agreed that these hazards are compounded by both wet snow (spring) conditions and the likelihood of having to open and close the pass.

Parting Comments

Below are responses to one of four evaluation questions posed to participants and observers for the three days, "what was most useful to you in this process?"

- "The entire session was very useful in observing the interactions and input into going through the ORMA process."
- "The positive, professional give and take among the panel members and the respectful participation of the observers resulted in really good information."
- "Participation by operational personnel, especially Lake District Ranger and Maintenance Foreman."

- “Opportunity for dialogue; relationship building.”
- “The exposure to this method of evaluating risk was very useful to me. Also very useful to me was the opportunity to participant in this very important process.”

A Caution Offered

- “The ORM appears to be an excellent tool to characterize risk. Its strength appears to be as a living document that can manage risk associated with specific tasks. I am not sure of the validity of this application with respect to the selection of management alternatives for Sylvan Pass. The results of this work could be taken out of context or misapplied.”

Comparisons with Past Risk Assessment(s)

There was a 2006 risk assessment conducted in Yellowstone by NPS staff that used a private sector model with 11 people providing input. Comments regarding this assessment include the following:

- Some surprise results [are that these results] aren’t a little more similar. We went deeper here. There’s no doubt we analyzed significantly more mitigation strategies. Yet we considered property damage in 2006 and not this time.
- Last time we focused in on employee safety, and this time we looked at safety of employees and visitors.
- Environmental protection was considered more in 2006 and 25 year time frame last time versus our risk for one day here.

IV. Risk Model Findings

Individual GAR Assessments

Following are the GAR assessments for a passive mitigation option (snow shed), the most recent mitigation option (use of contract helicopter), and an active automated option (fixed gas system). Chart 1 illustrates how different activities affect risk profiles. Appendix A shows all the rating summaries for each option the expert panel considered.

- Operational elements known to affect risk to personnel are assessed and combined to make up a total risk score.
- Employee and public risk are both considered in the assessment.

GAR Assessment Discussion

Each of the identified components is known to influence the risk of an operation. Some components can be changed by NPS personnel and some may depend on the situation. For example, *Plannin*g may or may not be sufficient depending upon if the incident is emergent or not. If the incident is recurring and static, pre-planning may suffice.

The relationship between components is important to understand. While many activities may be inherently hazardous with several moderately rated components it may be that one component rates low and keeps the activity within an acceptable risk level. In this situation the total risk profile is dependent on a single element and could be considered fragile (where this single element tips it). A better scenario is an activity that has more equal levels of risk and remains acceptable since it is an inherently more stable (less fragile, more balanced) profile.

Recognizing an activity where one or two operational components rate high is also important as it represents a potential to lower an overall risk profile by making only a few changes to the operation.

GAR Risk Profiles Compared

Chart 2 illustrates total risk scores for all avalanche control options discussed in the workshop.

- Note that *Access* is considered its own activity and receives its own risk score secondary to its own inherent hazards.
- The risk exposure of *Access* must be considered with those activities that require personnel to access the pass.
- With some exceptions risk increases consistently as you progress from passive, to active automated, to active mitigation techniques.
- Exceptions to the above include the use of *Full Forecasting* and to some degree *Backcountry Standards* and *Window Closure*.
- There are some inconsistencies.

Risk Profile Discussion

The risk profile scores are products from the collaboration of the subject matter experts making assessments from a programmatic context. The ORM process, when assessing a single operational mission just prior to its start, applies guidelines and mandates on what actions need to occur based on the mission's risk profile.

The inconsistency is the use of howitzer and howitzer with access mitigation risk profiles didn't change even though one would expect that intuitively. Reasons could be a misunderstanding of the panel or the intrinsic risks of using the artillery overshadows the risk of accessing the platform.

Access (referring to the travel from the Ranger station to the staging area on Sylvan Pass) is identified as being an independent hazardous activity. This is relevant because access to the staging area is required for many of the mitigation options and so increases the overall risk profile of those options including Full Forecasting, Helicopter, Trolleys, Hand Charges, Artillery, Avalauncher/LOCAT, and all of the hybrid combinations.

The severe environment, lack of contingency resources and low supervision are reasons accessing the pass have an elevated risk profile. Other factors that differentiate this activity from other winter overland travel include a potential sense of urgency, decreased flexibility in planning, and higher potential for poor weather conditions when combined with some mitigation options.

Some passive mitigation options such as *Tunnels, Snow-sheds, Start Zone Structures,* and *Full Closure* consistently rate low because of their high effectiveness of eliminating avalanche/human contact with little or no need to use personnel. The more an activity exposes personnel and introduces human error into an operation the higher the risk profile. The use of *Sails* and *Berms* also show low risk profiles however they were assessed by the group later to have poor effectiveness in controlling avalanches so their risk profile could be considered higher than shown.

Most of the risk associated with *Backcountry Standards* and *Window Closure* represent potential hazards to the public because a) *Backcountry Standards* warn the public of avalanche hazards but allows full access in any conditions, and b) With Window Closure there is the potential for having to re-close and open the pass in spring due to unexpected late season storms and the extra uncertainty that exists with spring snow and wet slab conditions. This increases odds of human error, though the profile is very consistent across all components.

Full Forecasting is the highest rated passive option due to the difficulty in forecasting without additional tools and the inability to "move snow" with other mitigation tools. With current resources and without other active techniques, predicting when to open and close Sylvan Pass is difficult and potentially inaccurate. This increases the odds of having unexpected natural release avalanches involving staff and/or public. This is represented in the high rating of the incident complexity, environment, and team components. It was also noted that this option might be the most susceptible to the negative influences of external pressures to "forecast" Sylvan Pass as safe to keep open.

GAR Operational Component Scores Compared

Chart 3 illustrates how operational components affect risk profiles consistently and programmatically.

- Environmental factors, Incident Complexity, and Contingency Resources are consistently high.

- Communication is consistently low.
- There are some inconsistencies when compared between option categories and personnel influences (passive, active, active automated, and hybrids.
- These trends are important when considering strategies to lower risk profiles.

GAR Operational Component Score Discussion

The environmental factors that affect personnel performance (and equipment) are significant in almost all options. The hazards include extreme temperatures, wind, elevation, precipitation, navigational hazards, and vertical exposure. It is impossible to eliminate all of these hazards but attempts have been made to eliminate some by installing a warming hut at the artillery platform (OSHA requirement). It was noted by the panel that team selection and team fitness currently offsets some of these hazards because the current team happens to be exceptionally experienced as well as acclimatized to the weather conditions, but that will change over time as staff experiences turnover.

The complexity of Sylvan Pass avalanche control work increases the likelihood of negative safety incidents. The complexity of actual work (including forecasting), constantly changing conditions, and typical length of exposure are all prominent factors. This is reflected in the profiles of *Full Closure, Avalauncher/LOCAT, Hand Charges,* and *Hybrid Helicopter/Artillery.* Incident Complexity is often intrinsic to tasks and environments but can be managed by improved planning (contingency) and communication (better information).

Contingency Resources risk components score high in all non-passive options. Factors that contribute to hazard include the distance **(**approximately 20 miles from Lake to the initial avalanche paths, and approximately 6 miles from the east entrance to Brown Drifts and approximately 68 miles to Cody**)** from the nearest resources to Sylvan Pass and consequently the amount of time it takes resources to respond. Complicating factors include hazardous emergency transit, as resources would have to contend with the same *Access* issues in addition to possibly being cut off by existing avalanche slopes. Another factor that contributes is availability, because of staffing, scheduling, weather, and other normal operational logistics there is no system in place to assure resources exist where they would be expected. The Contingency Resources component is compounded when utilizing a helicopter due to the additional areas and landscapes resources could potentially have to respond to.

Communication is a single component that is low in all options. Good radio infrastructure, ability to work face to face, and some structured established commands (as in *artillery*) facilitate operational communication. Because communication is consistently low it represents in some options the only component that offers any margin of error. (Options with helicopter use appear to depend on good communication to lower an already moderate risk profile).

One relative inconsistency in these profiles, and thus a caution, is the overall mid to low rating of team fitness and team selection. Considering that most of these control options (especially active options) require up to 3 personnel and the total available pool of qualified personnel is 4 it seems that these logistical restraints should have more of an impact to operations. The applied risk may be “captured” elsewhere in the panel’s assessments but it should be noted that the operational categories of team fitness/selection are other potential areas for improvement.

These trends are useful to consider when managing risk in an operation. Programmatic mitigation strategies that could potentially apply to several options include 1) use of different vehicles to provide environmental protection during access, 2) Use of control tactics that limit exposure to environment, 3) Use of localized weather/forecasting data to improve quality of information, 4) Dedicated forecasters to increase accuracy and decrease complexity, 5) Use of additional staff in operation for purpose of increasing contingency options, and 6) engineer to eliminate human risk and error.

Severity, Probability, Exposure Comparison

As a way to quantify the differences in avalanche control risks on Sylvan Pass and Talus Slope the panel conducted a SPE assessment on both locations. The panel was asked to assess the SPE components for both sites in the context of what they thought could occur over a five-year period. Considerations include historical knowledge, traffic, and the unique qualities of both slopes and their specific hazards. The panel was also asked to consider risks to employees and visitors.

Though there was some confusion in applying this model in this framework the assessments were consistent in recognizing a higher risk at Sylvan (Average sum of 10.3) than at Talus (Average sum of 2.1). Of the 3 components Severity consistently rated higher at Sylvan (all panelists rated the maximum score of 5) compared to Talus (average score of 1). Panelists assessed the probability of a negative event occurring nearly twice as high at Sylvan than at Talus (average 2.9 vs. 1.5). Of special note all panelists assessed exposure (including amount of time, number of people involved, repetitions) average or below average for both Sylvan and Talus.

Risk vs. (Factual) Gain

Assessing risk vs. gain is an important part of risk management and one of the primary principles of the ORM process. Individual missions identify gain as a single mission objective. Programmatic gain is measured in several areas considered to be *Universal Risk Considerations* including:

- Injury, occupational illness or death
- Equipment, Fiscal resource impacts
- Mission success/failure
- Adverse or positive public impacts
- Morale impacts
- Administrative and/or disciplinary impacts

The expertise contained in the working panel could also evaluate potential gains, based on *facts*, related to the avalanche control options. The primary consideration is the safety of personnel and is the focus of this assessment therefore the risk should be compared to the overall gains. The “factual” gains assessed include:

- **Risk**. Measured and quantified by the GAR risk profile score and used to compare with other factual gains (high score = high risk)
- **Effectiveness**. An assessment of how well the avalanche control option performs its objective of eliminating negative avalanche/people contact. (high score = highly effective)
- **Pass Access**. An assessment of how well the avalanche control option keeps Sylvan Pass open to traffic. A numeric score of 2 is equivalent to 18 days. Only days between December 15th and March 15th were considered (high score = fewer closers).

- **Natural Resource avoidance**. An assessment of how well the avalanche control option avoids structures and other impacts to the designated wilderness surrounding Sylvan pass (high score = low impact)
- **Cost**. An assessment of how much the avalanche option would cost to implement. A general scale evenly dividing range* of costs from 3.5 million to 100,000. * Tunnel, snow-shed and starting zone structures costs were out of scale (20 to 30 million) and noted (high score = low cost).

Chart 4 illustrates the panel's quantification of gain from lowest to highest.

- It is important to consider ratios of gain.
- Organizational values must be applied.
- Other Universal Risk Considerations must be considered.
- How would these "gains" change with operational changes implemented to decrease risk?

Discussion

Tunnels and support structures possess the highest percentage of gain *except* for "cost" which is nearly ten times as much as the next highest option (fixed gas). For consistency the gain is considered zero for these options.

There was no attempt to apply values, either personal or organizational, to this risk vs. gain assessment. The ratings given to each of these "factual" categories was based on technical and objectives information.

Chart 4 only shows a relationship of total factual gain measures between each mitigation option (Ratios of gain components are illustrated later) and is valuable for seeing trends in options. Unlike the risk profile data, the relationship between passive, active automated, and active avalanche control options does not exist confirming that even without values attached to factual gains some option categories do not provide a viable solution.

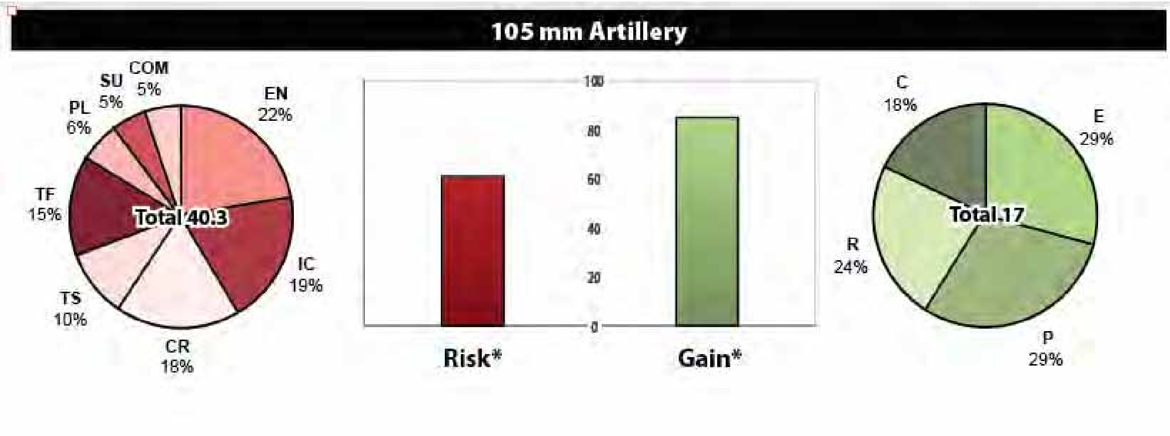
As these are values based solely on operational facts it may be important to place organizational values on each of the "gain" categories to further measure the benefits (i.e. if the organization places a higher intrinsic value on fiscal resources the "cost" component of measured gain would change the profile).

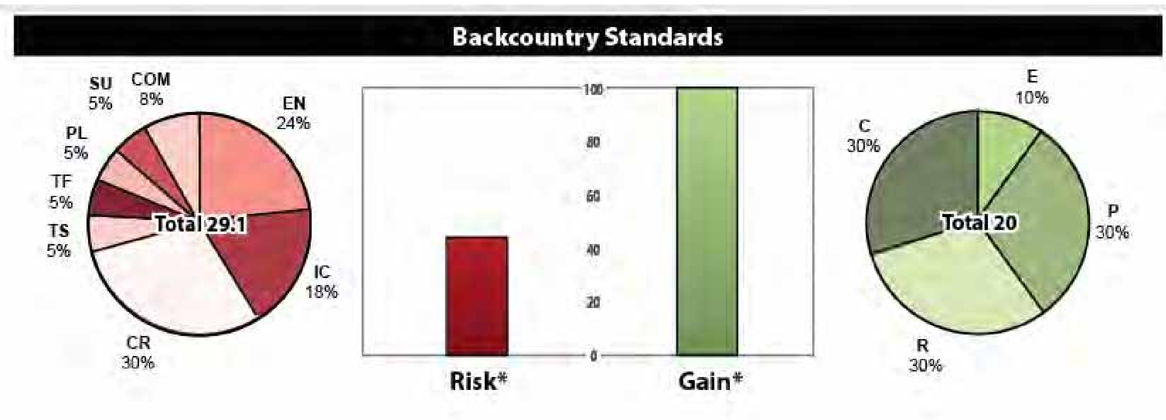
The universal risk considerations of fiscal resource impacts and mission success are represented by quantifying Cost, Pass Access, Effectiveness, and Natural Resource Avoidance in this assessment. The other considerations of Morale, adverse or positive publicity, and administrative and/or disciplinary impacts could not be evaluated by this work group.

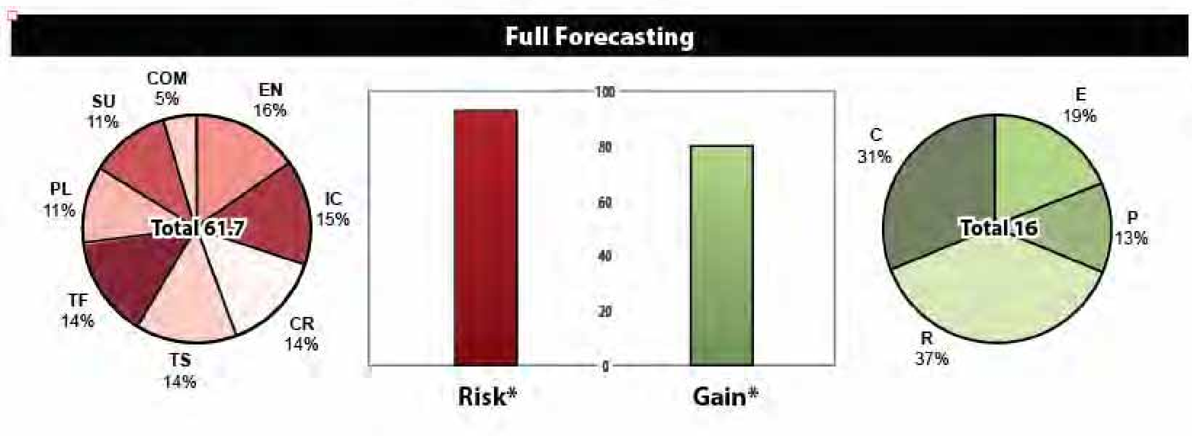
This is a static snapshot of these avalanche control options with current and available resources. If operational changes (assuming improvements) were made the ratio would improve also. Full Forecasting, Window Closure, Backcountry Standards, and hybrid Closure with Helicopter are options in which, if changes were implemented to lower the total risk profile, those changes would also increase factual gain measurements (in effectiveness and pass access). Typically, as operational mitigation changes are made gain measurements drop.

The elements of Chart 5 illustrate the relationship and ratio of risk vs. gain within individual avalanche control options.

Several examples of risk vs. gain ratios from Chart 5:







KEY TO ABBREVIATIONS

EN	Environment	**TF**	Team Fitness
IC	Incident Complex	**PL**	Planning
CR	Contingency Recs	**SU**	Supervision
TS	Team Selection	**COM**	Communication

KEY

E	Effectiveness
P	Pass
R	Resources
C	Cost

* The options with the highest Risk and highest Gain are calibrated as equal to 100. Thus Hand Charges Risk = 100 and Backcountry Gain = 100. All other options correspond to these calibrations.

- It’s important to consider which components of both risk and gain make up the total profile as compared to each other.
- Consider which risk components can be mitigated and which gain components carry more value. (Value should not drive risk).
- Review consistent and programmatic operational components and identify where these influence profile ratios (Environmental factors, Incident Complexity, and Contingency Resources).

Discussion

The ideal ratio is a low risk/high gain model. As this data is based on current operations one has to look further inside each score to consider operational improvements.

If the organization can place more value on any of the gain components that potential change should be noted as it affects total ratio (i.e. if cost has a high organizational value an increase in gain ratio should be expressed for those options showing a larger cost component). Conversely, gain should not drive the risk (i.e. if cost is a high organizational value changes should not be made to strengthen the cost gain component as it will negatively affect risk).

In reviewing what operational components present consistently high in a program identify which ratios can be improved. If Environmental Factors, Incident Complexity, and Contingency Resources components were programmatically improved (lowering risk profile) for those options that show significant gain, more viable options may be available.

V. Continuing the Process: Considerations in Using this Assessment

The primary objective of this assessment is to provide an accurate and general measurement of the risk contained in both current and potential Sylvan Pass avalanche control operations. To meet this objective several models have been used to study the intrinsic risk. This report describes and illustrates:

- Those factors specific to Sylvan Pass that provide hazards and affects risk to personnel.
- Those hazards specific to all Sylvan Pass winter road corridor operations.
- Those operational components that affect risk to personnel in avalanche control activities.
- A measurement of personnel risk involved in past Sylvan Pass operations.
- A measurement of personnel risk involved in current Sylvan Pass operations.
- A measurement of risk to personnel involved in other potential avalanche control options.
- A comparison of risk measurements of combined avalanche control options.
- Risk trends in individual avalanche control options.
- Programmatic risk trends found in most control options.
- A measurement of factual gains directly related to each avalanche control option.
- A ratio measurement of risk vs. gain for each avalanche control option.

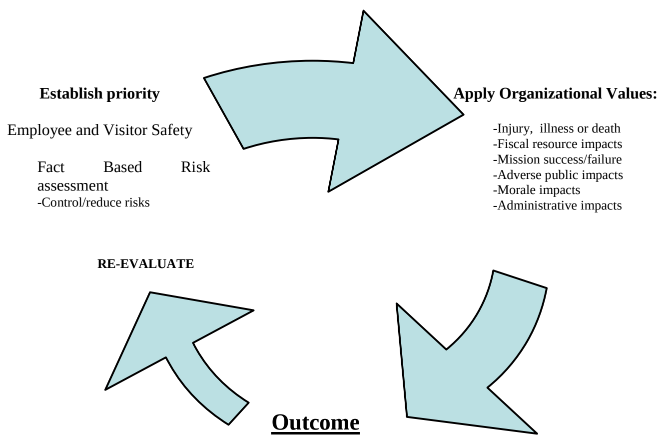
A weakness of this report is that it cannot provide an exact and precise assessment of any one single mission. All of the operational components can change from day to day depending on which individual showed up to work, weather conditions that day, and other dynamic factors. The principles and models used for this assessment can, and should, be used prior to personnel leaving their duty station in route to perform avalanche control on Sylvan Pass and it is only by doing this that a precise risk profile can be established for any one mission.

Another weakness of this report is that of evaluating potential operations in which the panel had expert knowledge of the technical aspects but not experiential knowledge of how it would specifically apply to Sylvan Pass and the work group that would conduct the operations. Some assumptions had to be made by the panel in quantifying those operational components.

This report also offers risk mitigation models as well as some suggestions that can apply to many of the avalanche control options. There are improvements that can be made to lower risk profiles for some of the options, which will also affect risk vs. gain ratios. What the report leaves to the reader and ultimately the Sylvan Pass operational staff are the assessments of operational risk after (potential) mitigations techniques have been implemented. As the decision to lower risk and by which mitigation techniques is an organizational one (based on value factors) this report and the panel that participated can only articulate that these options exist and should be considered. The assessments reported give an accurate representation of risk profiles for each control option and will accurately lead the reader to those options which can gain from operational changes.

Continued Process: Applying Values and Priorities

When assessing operational components and applying numeric scores there is limited opportunity to apply subjective reasoning. As experts in avalanche control and sylvan pass operations the panel was asked to base their assessments on what was realistic and based on fact. The next step in applying the operational risk management process is applying values.



It should be common for an organization's priority to be their employees' safety but it is rare for it to be *only* priority. Other considerations that also contain risk must be assessed often times with values attached. Financial risks, local and long term repercussions to the organizations mission, external opinion and relationships, and internal staffing concerns all possess different ratios of risk and gain.

The following is a decision tree that utilizes the findings from this report's assessment on personnel risk (1st priority) and places the second and third priorities on effectiveness and cost.

Table 9. Control Options with < 36 Total Risk Profile, Effectiveness

Options	Effectiveness > ½ scale	Cost > ½ scale	Viable Options
Total closure	Total closure	Total Closure	
Tunnel/snowshed	Tunnel/snowshed	NA	
Support in start zones	Support in start zones	NA	
Backcountry standards	Backcountry standards	Backcountry standards	Backcountry standards.
Window closure	Window closure	Window closure	Window closure
Fixed gas system	Fixed gas system	NA	
Trolleys	Trolleys	NA	
Berms/deflectors/basins	NA	NA	
Snow sails	NA	NA	
Closure w/ helo. to open	Closure w/ helo.	Closure w/ helo.	Closure w/ helo.

The following is another decision tree which utilizes the findings from this reports assessment with personnel safety the first priority, an open Sylvan Pass a second priority, and effectiveness a third priority.

Table 10. Control Options with < 36 Total Risk Profile, Open Pass

Options	Open Pass > ½ scale	Effectiveness>½ scale	Viable Options
Total closure	NA	Total Closure	
Tunnel/snowshed	Tunnel/snowshed	Tunnel/snowshed	Tunnel/snowshed
Support in start zones	Support in start zones	Support in start zones	Support in start zones
Backcountry standards	Backcountry standards	Backcountry standards	Backcountry standards
Window closure	NA	Window closure	
Fixed gas system	Fixed gas system	Fixed gas system	Fixed gas system
Trolleys	Trolleys	Trolleys	Trolleys
Berms/deflectors/basins	NA	NA	
Snow sails	NA	NA	
Closure w/ helo. to open	NA	Closure w/ helo. to open	

Compare and consider the results on the above decisions trees if combined. Backcountry standards would be the only viable option.

If you consider accepting a higher risk profile (either with the assumption that we can mitigate some of the inherent risk or that the potential gain makes it worthwhile) while adding a fourth priority of resource impact you have more initial options.

Table 11. Control Options with < 47 Total Risk Profile, 4 Priority Model

Option	Open Pass	Effectiveness-	Res. impact>½ scale	Viable Options
Total closure	NA	NA	Total Closure	
Tunnel/snowshed	Tunnel/snowshed	Tunnel/snowshed	Tunnel/snowshed	Tunnel/snowshed
Support in start zones	Support in start zones	Support in start zones	NA	
Backcountry standards	Backcountry standards	Backcountry standards	Backcountry standards	Backcountry standards
Window Closure	NA	Window Closure	Window Closure	
Fixed gas system	Fixed gas system	Fixed gas system	NA	
Trolleys	Trolleys	Trolleys	NA	
Berms/deflectors/basins	NA	NA	NA	
Snow sails	NA	NA	NA	
Closure w/ helo. to open	NA	Closure w/ helo. to open	Closure w/ helo. to open	
Artillery	Artillery	Artillery	Artillery	Artillery
Artillery + Access mit.	Artillery + Access mit.	Artillery + Access mit.	NA	
Fixed Gas + helo	Fixed Gas + helo	Fixed Gas + helo	NA	

As an organization better understands what hazards and risks threaten an operation new options become viable and other options become unacceptable. These decision trees when used with the organizations other risk considerations and the attached values are useful in designing durable operations and unassailable decisions. The final step is an ongoing commitment to re-assess and re-evaluate, always beginning first with those risks that affect personnel safety.

Appendix A

Risk Model Data

Table A-1. Risk Model Data

Option	Scorer 1	Scorer 2	Scorer 3	Scorer 4	Scorer 5	Scorer 6	Scorer 7	Average
ACCESS								
Supervision	8	7	7	7	7	5	8	7
Planning	4	3	4	6	5	6	6	4.857142857
Contingency Recs	7	3	8	6	8	9	8	7
Communication	2	2	2	2	2	2	2	2
Team Selection	8	3	8	5	6	7	8	6.428571429
Team Fitness	4	5	5	3	3	9	4	4.714285714
Environment	9	10	8	8	8	8	10	8.714285714
Incident Complex	4	3	6	6	4	8	10	5.857142857
Total	46	36	48	43	43	54	56	46.57142857
HELICOPTER AV CONTROL								
Supervision	9	7	9	9	9	8	8	8.428571429
Planning	7	4	7	8	7	3	7	6.142857143
Contingency Recs	7	5	9	8	9	8	9	7.857142857
Communication	2	3	2	3	3	2	3	2.571428571
Team Selection	8	5	8	9	8	6	9	7.571428571
Team Fitness	7	4	8	5	6	3	3	5.142857143
Environment	10	10	9	9	9	10	10	9.571428571
Incident Complex	8	4	9	8	8	8	10	7.857142857
Total	58	42	61	59	59	48	59	55.14285714
FIXED GAS SYSTEMS								
Supervision	2	2	2	2	2	3	2	2.142857143
Planning	2	4	2	6	4	4	2	3.428571429

Option	Scorer 1	Scorer 2	Scorer 3	Scorer 4	Scorer 5	Scorer 6	Scorer 7	Average
Contingency Recs	3	3	4	3	3	4	7	3.857142857
Communication	2	2	2	2	2	3	3	2.285714286
Team Selection	3	3	3	3	2	4	3	3
Team Fitness	2	2	2	3	2	3	3	2.428571429
Environment	8	10	3	5	7	3	10	6.571428571
Incident Complex	5	3	3	5	6	3	4	4.142857143
Total	27	29	21	29	28	27	34	27.85714286
TROLLEY/TRAM								
Supervision	3	2	2	2	2	6	3	2.857142857
Planning	3	4	3	4	4	6	2	3.714285714
Contingency Recs	4	3	4	4	7	7	9	5.428571429
Communication	2	2	2	2	2	2	3	2.142857143
Team Selection	3	3	3	2	3	3	3	2.857142857
Team Fitness	2	2	3	2	3	5	3	2.857142857
Environment	9	10	4	7	7	7	10	7.714285714
Incident Complex	7	5	5	5	5	3	7	5.285714286
Total	33	31	26	28	33	39	40	32.85714286
HAND CHARGES								
Supervision	8	7	7	7	7	8	8	7.428571429
Planning	9	7	8	7	8	8	9	8
Contingency Recs	8	8	8	9	8	9	9	8.428571429
Communication	4	3	4	3	4	7	5	4.285714286
Team Selection	10	10	10	8	10	10	10	9.714285714
Team Fitness	10	10	10	9	10	10	10	9.857142857

Option	Scorer 1	Scorer 2	Scorer 3	Scorer 4	Scorer 5	Scorer 6	Scorer 7	Average
Environment	10	10	9	10	9	10	10	9.714285714
Incident Complex	9	8	9	10	9	9	10	9.142857143
Total	68	63	65	63	65	71	71	66.57142857
FULL BLOWN FORECASTING								
Supervision	8	5	8	9	8	6	6	7.142857143
Planning	8	8	8	9	7	6	2	6.857142857
Contingency Recs	8	8	8	10	9	8	9	8.571428571
Communication	3	3	4	2	2	3	3	2.857142857
Team Selection	9	8	9	8	10	9	9	8.857142857
Team Fitness	9	8	9	8	10	8	9	8.714285714
Environment	9	10	8	10	9	10	10	9.428571429
Incident Complex	8	10	9	10	9	10	9	9.285714286
Total	62	60	63	66	64	60	57	61.71428571
BACKCOUNTRY STANDARDS								
Supervision	1	2	2	2	1	2	1	1.571428571
Planning	1	2	2	1	1	2	1	1.428571429
Contingency Recs	9	9	5	8	10	10	9	8.571428571
Communication	2	3	2	2	4	2	2	2.428571429
Team Selection	2	2	1	2	2	1	1	1.571428571
Team Fitness	2	2	1	2	2	1	1	1.571428571
Environment	9	10	5	8	8	2	5	6.714285714
Incident Complex	5	4	9	2	10	2	5	5.285714286
Total	31	34	27	27	38	22	25	29.14285714

Option	Scorer 1	Scorer 2	Scorer 3	Scorer 4	Scorer 5	Scorer 6	Scorer 7	Average
TOTAL CLOSURE								
Supervision	1	1	1	1	1	1	1	1
Planning	1	1	1	1	1	1	1	1
Contingency Recs	1	1	1	1	1	1	1	1
Communication	1	1	1	1	1	1	1	1
Team Selection	1	1	1	1	1	1	1	1
Team Fitness	1	1	1	1	1	1	1	1
Environment	1	1	1	1	1	1	1	1
Incident Complex	1	1	1	1	1	1	1	1
Total	8	8	8	8	8	8	8	8
WINDOW CLOSURE								
Supervision	2	3	3	2	2	7	3	3.142857143
Planning	2	4	3	2	2	7	2	3.142857143
Contingency Recs	5	3	4	2	4	6	9	4.714285714
Communication	2	3	2	2	1	2	2	2
Team Selection	2	4	3	4	5	7	2	3.857142857
Team Fitness	2	4	3	2	5	8	2	3.714285714
Environment	5	6	3	2	6	5	7	4.857142857
Incident Complex	7	3	5	4	4	4	4	4.428571429
Total	27	30	26	20	29	46	31	29.85714286
105 MM ARTILLERY								
Supervision	2	2	2	2	2	2	2	2
Planning	2	4	3	2	2	2	2	2.428571429
Contingency Recs	7	4	7	8	7	9	9	7.285714286

Option	Scorer 1	Scorer 2	Scorer 3	Scorer 4	Scorer 5	Scorer 6	Scorer 7	Average
Communication	2	2	2	2	2	2	3	2.142857143
Team Selection	4	3	2	7	2	4	5	3.857142857
Team Fitness	7	6	8	7	3	5	5	5.857142857
Environment	10	10	9	10	8	6	10	9
Incident Complex	9	6	7	9	8	6	9	7.714285714
Total	43	37	40	47	34	36	45	40.28571429
BERMS, DEFLECTORS, CATCH BASINS								
Supervision	1	1	1	1	1	3	1	1.285714286
Planning	1	1	1	6	5	2	1	2.428571429
Contingency Recs	1	1	1	6	3	2	1	2.142857143
Communication	1	3	1	1	1	2	1	1.428571429
Team Selection	1	1	1	1	1	2	1	1.142857143
Team Fitness	1	1	1	1	1	2	1	1.142857143
Environment	1	1	1	1	2	3	1	1.428571429
Incident Complex	9	8	9	10	5	3	7	7.285714286
Total	16	17	16	27	19	19	14	18.28571429
SNOW SAILS								
Supervision	1	1	1	1	1	1	1	1
Planning	1	1	1	6	2	1	1	1.857142857
Contingency Recs	1	1	1	8	1	1	1	2
Communication	1	3	1	1	1	1	1	1.285714286
Team Selection	1	1	1	1	1	1	1	1
Team Fitness	1	1	1	1	1	1	1	1
Environment	1	1	1	10	5	1	1	2.857142857

Option	Scorer 1	Scorer 2	Scorer 3	Scorer 4	Scorer 5	Scorer 6	Scorer 7	Average
Incident Complex	9	8	9	10	6	7	7	8
Total	16	17	16	38	18	14	14	19
AVALAUNCHER/LOCAT								
Supervision	7	2	7	6	6	8	2	5.428571429
Planning	3	4	5	9	7	8	2	5.428571429
Contingency Recs	5	4	7	8	8	9	9	7.142857143
Communication	2	2	2	2	2	2	3	2.142857143
Team Selection	7	3	8	6	5	7	5	5.857142857
Team Fitness	7	6	8	4	5	7	5	6
Environment	9	10	7	10	10	8	10	9.142857143
Incident Complex	10	8	9	10	9	8	10	9.142857143
Total	50	39	53	55	52	57	46	50.28571429
TUNNEL, SHED, SUPPORT STRUCTURES								
Supervision	1	1	1	1	1	1	1	1
Planning	1	1	1	1	1	1	1	1
Contingency Recs	1	1	1	1	1	1	1	1
Communication	1	1	1	1	1	1	1	1
Team Selection	1	1	1	1	1	1	1	1
Team Fitness	1	1	1	1	1	1	1	1
Environment	1	1	1	1	1	1	1	1
Incident Complex	1	1	1	1	1	1	1	1
Total	8	8	8	8	8	8	8	8
HELO HOWITZER								
Supervision		6	6	6	8	7	7	6.666666667

Option	Scorer 1	Scorer 2	Scorer 3	Scorer 4	Scorer 5	Scorer 6	Scorer 7	Average
Planning		6	7	6	6	7	7	6.5
Contingency Recs		5	7	5	8	8	9	7
Communication		3	3	3	3	2	3	2.833333333
Team Selection		5	8	8	8	7	9	7.5
Team Fitness		6	8	6	5	8	4	6.166666667
Environment		10	9	10	10	8	10	9.5
Incident Complex		10	8	9	8	9	10	9
Total		51	56	53	56	56	59	55.16666667
HOWITZER + ACCESS MITIGATION								
Supervision		3	2	3	2	2	2	2.333333333
Planning		5	3	5	2	5	2	3.666666667
Contingency Recs		3	6	5	6	9	9	6.333333333
Communication		2	2	2	2	2	3	2.166666667
Team Selection		3	5	7	4	7	5	5.166666667
Team Fitness		6	6	6	4	7	5	5.666666667
Environment		10	9	9	6	8	10	8.666666667
Incident Complex		5	7	6	5	5	9	6.166666667
Total		37	40	43	31	45	45	40.16666667
FIXED GAS + HELO								
Supervision		3	4	4	3	7	3	4
Planning		4	4	6	4	7	4	4.833333333
Contingency Recs		3	7	6	5	8	9	6.333333333
Communication		2	2	2	2	2	3	2.166666667
Team Selection		3	4	5	5	4	4	4.166666667

Option	Scorer 1	Scorer 2	Scorer 3	Scorer 4	Scorer 5	Scorer 6	Scorer 7	Average
Team Fitness		2	4	4	4	4	4	3.666666667
Environment		10	8	7	7	7	10	8.166666667
Incident Complex		4	5	6	6	7	5	5.5
Total		31	38	40	36	46	42	38.83333333
CLOSURE + HELO								
Supervision		4	6	2	5	3	4	4
Planning		6	7	6	6	3	4	5.333333333
Contingency Recs		2	3	3	4	1	2	2.5
Communication		3	2	2	2	2	3	2.333333333
Team Selection		5	7	5	6	2	5	5
Team Fitness		4	5	3	5	1	3	3.5
Environment		4	7	6	6	2	4	4.833333333
Incident Complex		7	8	9	9	2	5	6.666666667
Total		35	45	36	43	16	30	34.16666667

Appendix B

Risk Versus Gain Data

Table B-1. Risk-Gain Comparison

Option	Risk	**Effectiveness** (where 6 is very, 0 is not)	**Pass** (where 6 is most open, 0 is most closed 90 day period*)	**Resources** (where 6 is low impact, 0 is high)	**Cost** (where 6 is low cost, 0 is high**)
Access	46.6				
Total Closure	8	6	0	6	6
Tunnel/Shed	8	6	6	5	X
Support Structures in Start Zones		5	6	0	X
Full Forecasting	62	3	2	6	5
Helicopter	55.1	4	3	5	4
Backcountry Standards	29.1	2	6	6	6
Window Closure	29.9	5	0	6	6
Fixed Gas Systems	27.9	5	5	2	2
Hand Charges	66.6	2	3	5	3
Trolleys	32.9	4	5	2	2
Artillery	40.3	5	5	4	4
Berms, Deflectors, Catchment Basins	18.3	1	1	1	1
Snow Sails	19	2	2	1	2
Avalauncher/LOCAT	50.3	2	2	4	3
Helo Howitzer	55.1	5	5	4	2
Howitzer + Access Mitigation	40.1	5	5	3	3
Closure + Helo	34.1	5	0	5	6
Fixed Gas + Helo	38	5	5	1	2

Notes:

*regarding openess: 2 means about 18 days, December 15 to March 15 is the winter season

** where 6 is about 0–$100K

4 is about $250K–$500K

3 is about $500K–$1.5 million

2 is about $1.5 million–$5 million

1 is about $5 million–$10 million

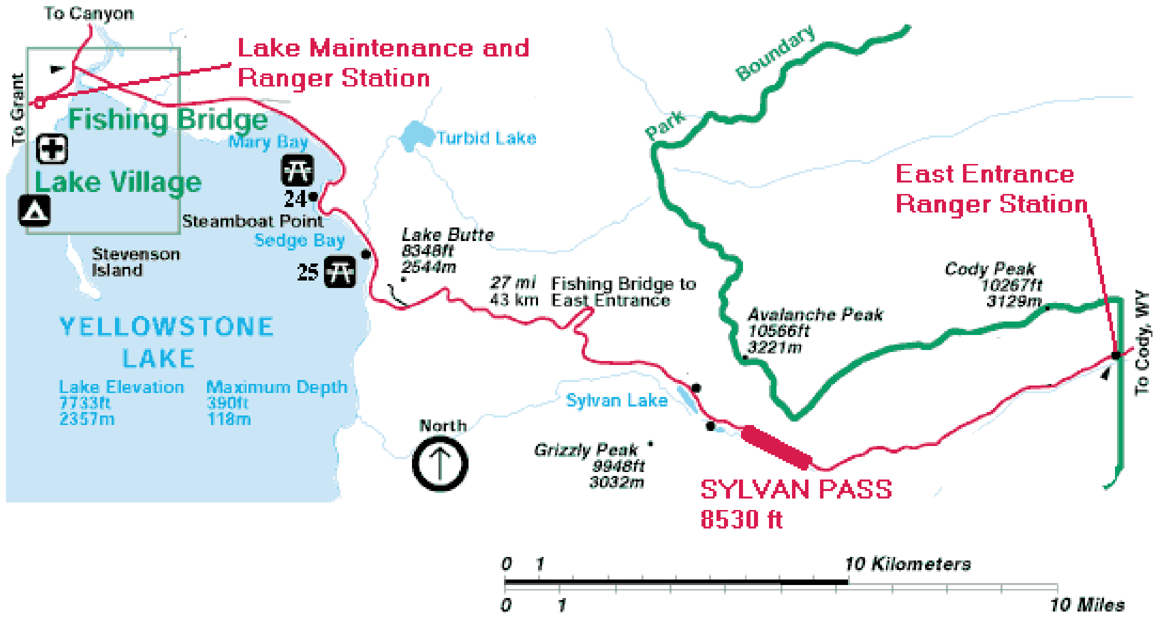
0 is about $10 million–$100 million

X represents orders of magnitude higher

Appendix C

Figures and Charts

Figure 1 Layout of the East Entrance Road
Yellowstone National Park



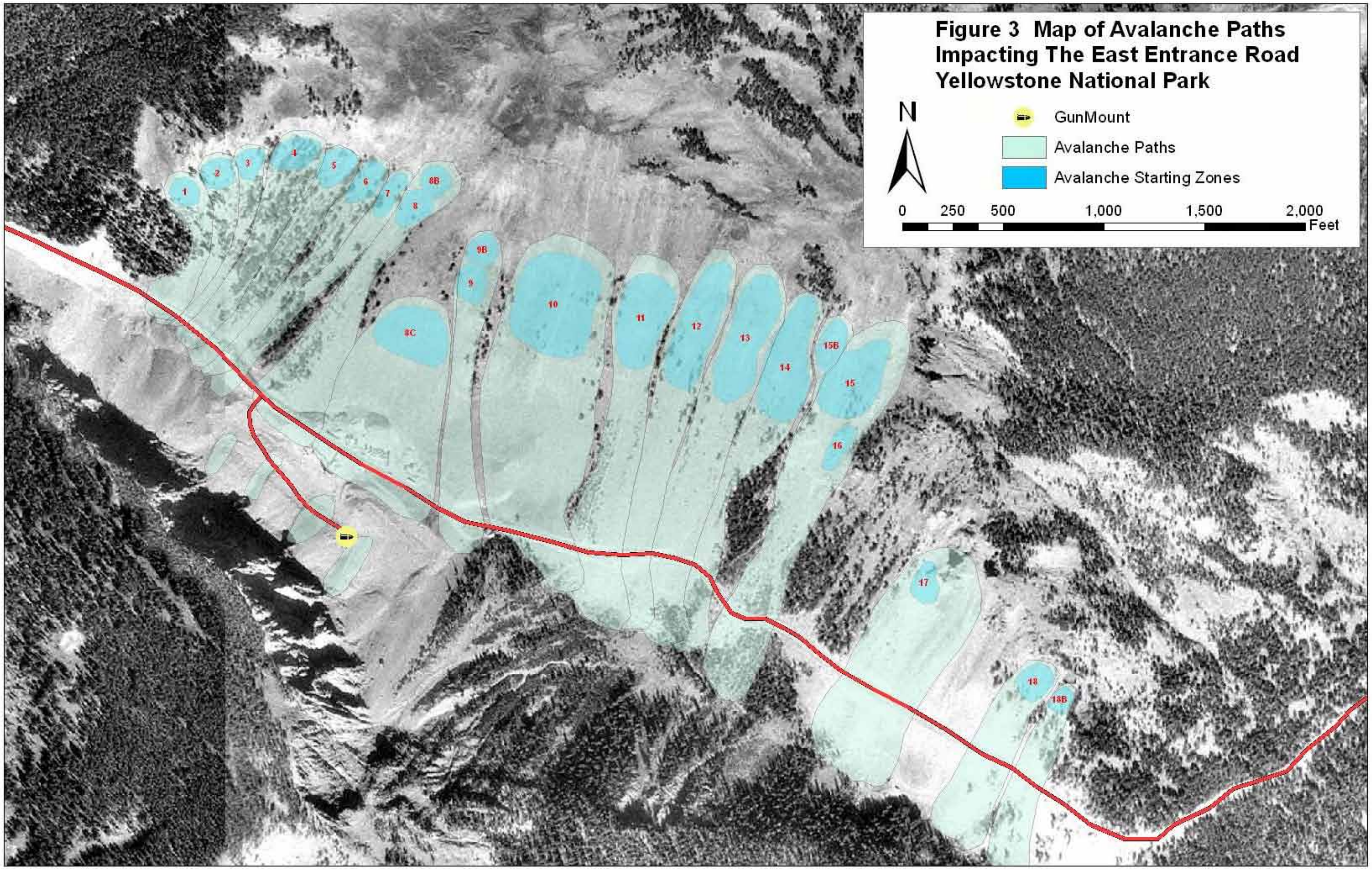


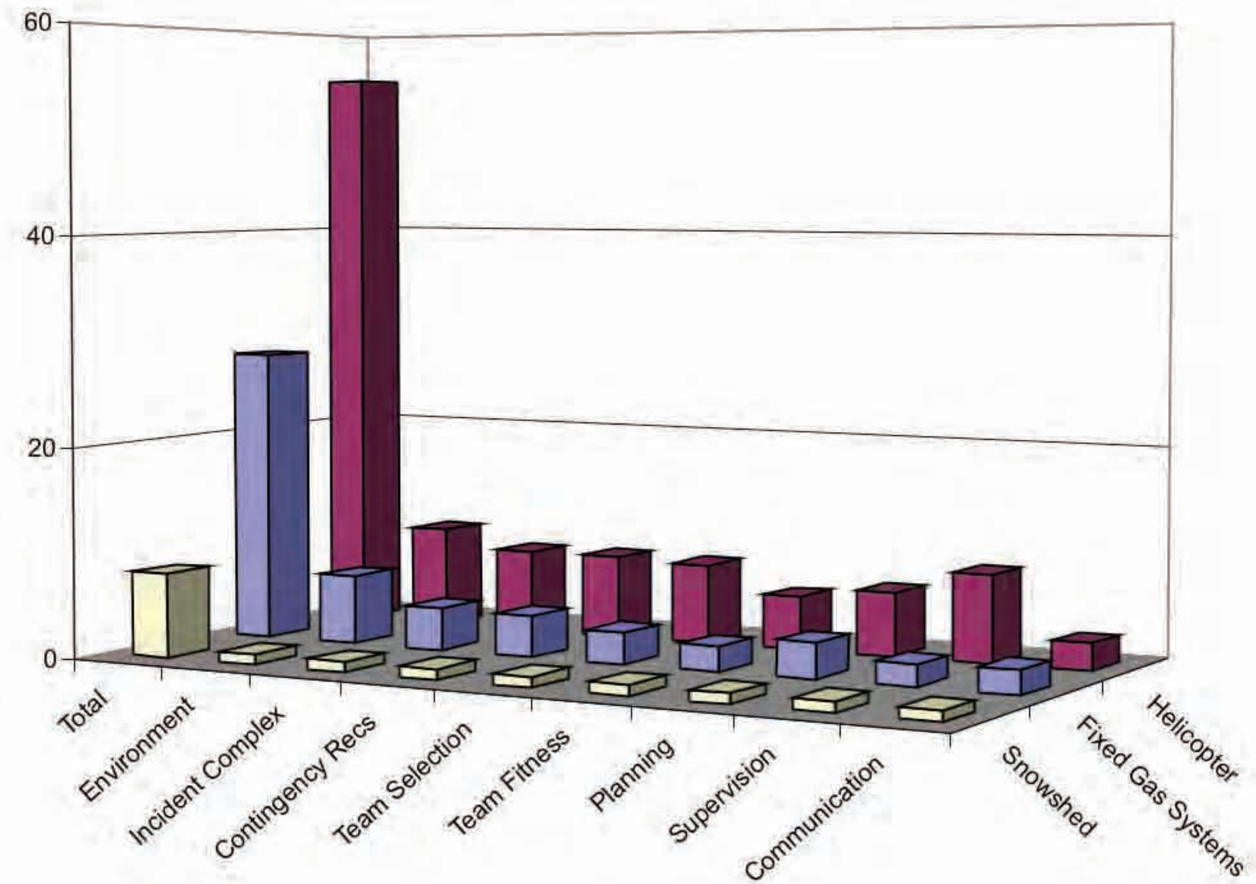
Figure 3 Map of Avalanche Paths
Impacting The East Entrance Road
Yellowstone National Park
N
GunMount
Avalanche Paths
Avalanche Starting Zones
0 250 500 1,000 1,500 2,000
Feet
1
2
3
4
5
6
7
8
8B
8C
9
9B
10
11
12
13
14
15
15B
16
17
18
18B

Figure 3
Comparison Photo of Talus Slope and Sylvan Pass

Figure 3. Comparison of Talus Slope (Left) and Sylvan Pass (Right)

Source: National Park Service

Chart 1. GAR Risk Assessments



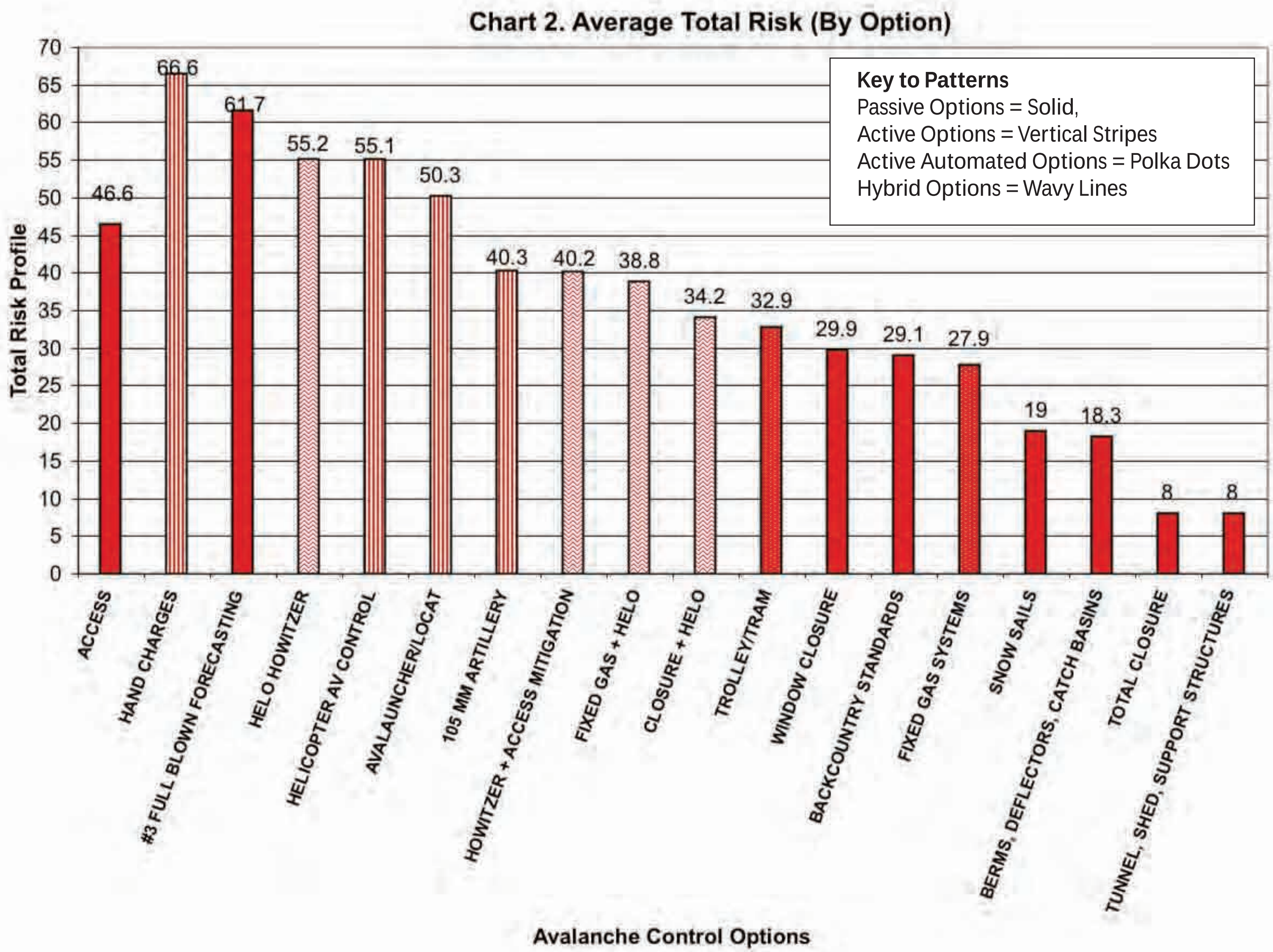


Chart 2. Average Total Risk (By Option)
Key to Patterns
Passive Options = Solid,
Active Options = Vertical Stripes
Active Automated Options = Polka Dots
Hybrid Options = Wavy Lines
Total Risk Profile
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
46.6
66.6
61.7
55.2
55.1
50.3
40.3
40.2
38.8
34.2
32.9
29.9
29.1
27.9
19
18.3
8
8
ACCESS
HAND CHARGES
#3 FULL BLOWN FORECASTING
HELO HOWITZER
HELICOPTER AV CONTROL
AVALAUNCHER/LOCAT
105 MM ARTILLERY
HOWITZER + ACCESS MITIGATION
FIXED GAS + HELO
CLOSURE + HELO
TROLLEY/TRAM
WINDOW CLOSURE
BACKCOUNTRY STANDARDS
FIXED GAS SYSTEMS
SNOW SAILS
BERMS, DEFLECTORS, CATCH BASINS
TOTAL CLOSURE
TUNNEL, SHED, SUPPORT STRUCTURES
Avalanche Control Options

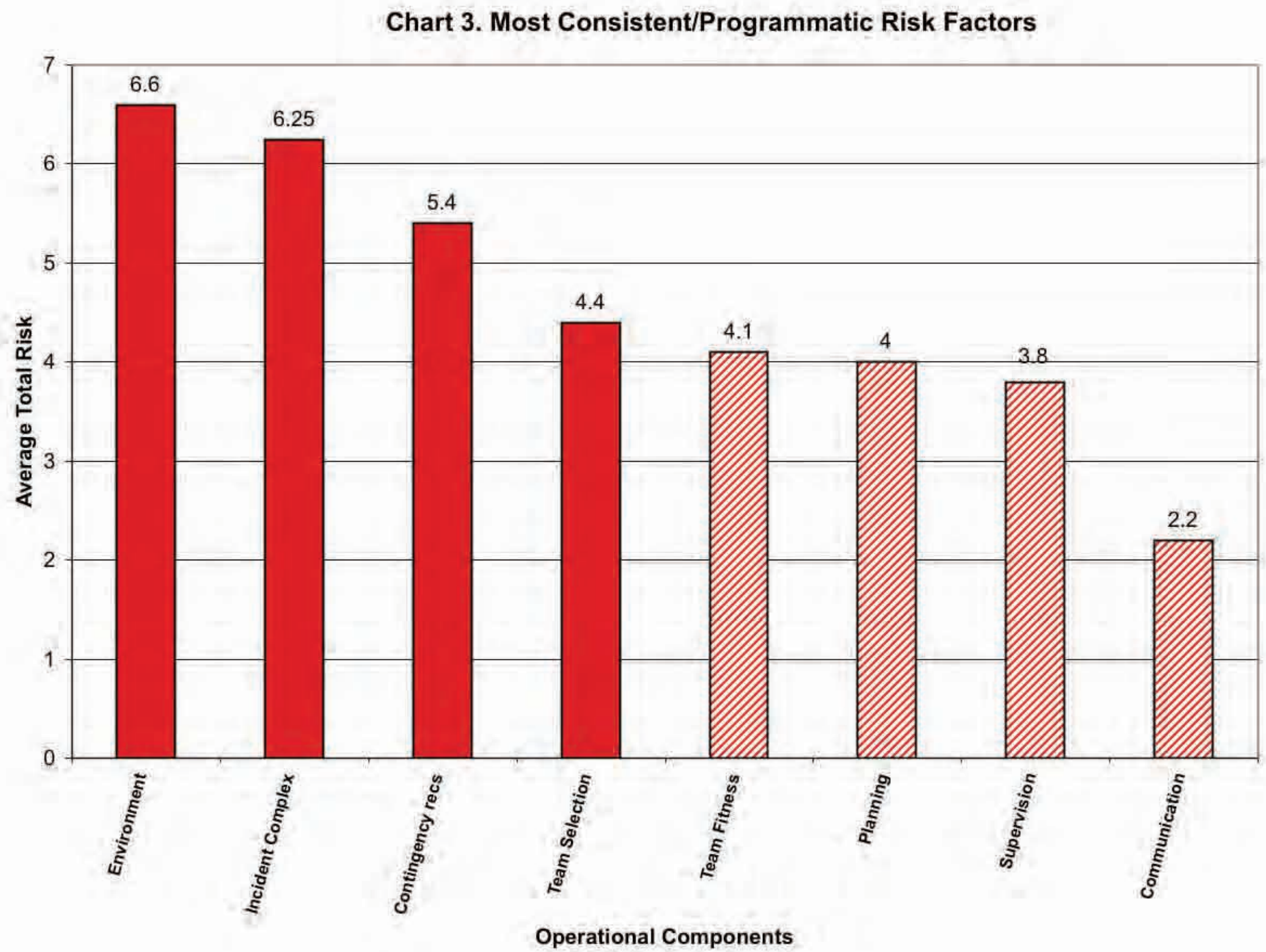


Chart 3. Most Consistent/Programmatic Risk Factors
Average Total Risk
0
1
2
3
4
5
6
7
6.6
6.25
5.4
4.4
4.1
4
3.8
2.2
Environment
Incident Complex
Contingency recs
Team Selection
Team Fitness
Planning
Supervision
Communication
Operational Components

Chart 4.Total Gains for Each Option

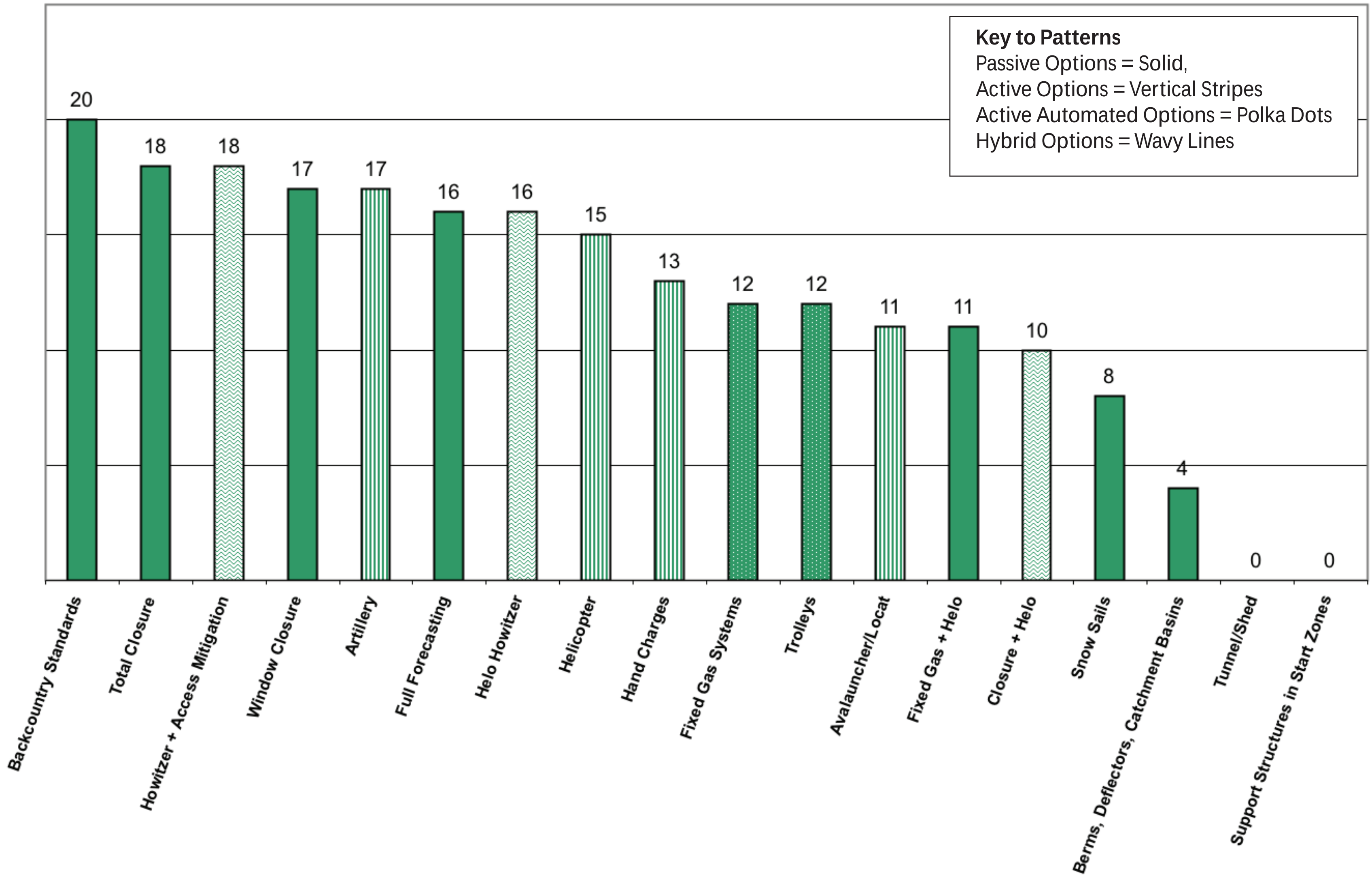
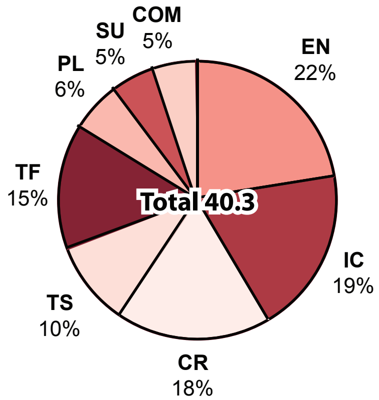
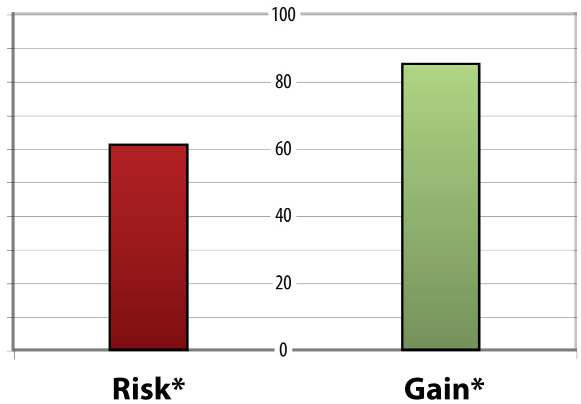
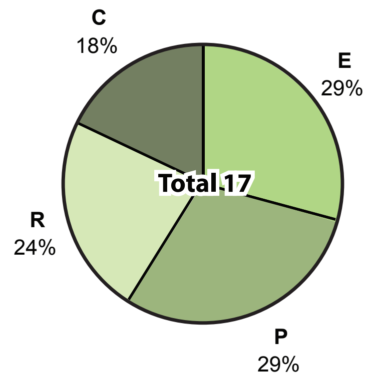


Chart 5. Risk-Gain Ratios

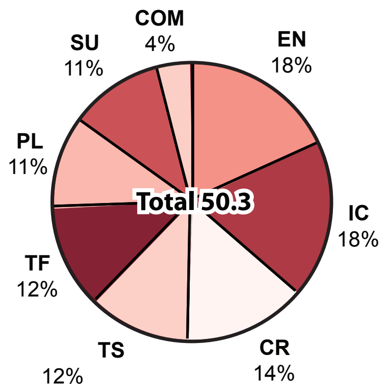
105 mm Artillery

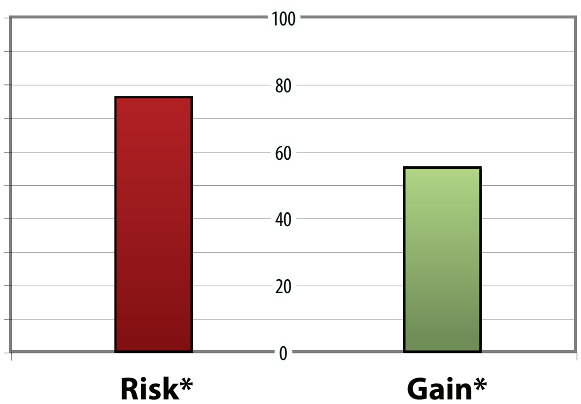


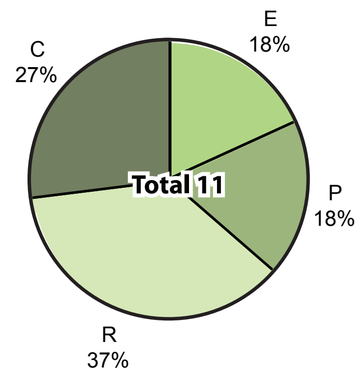




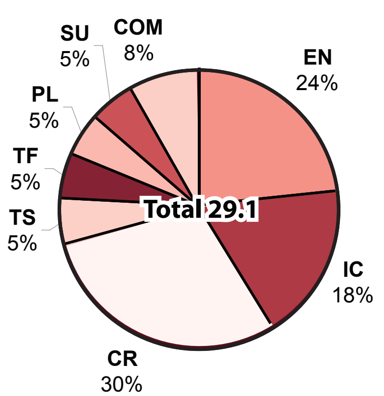
Avalauncher/Locat

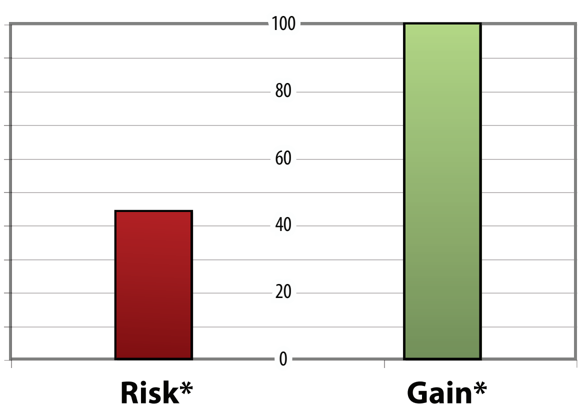


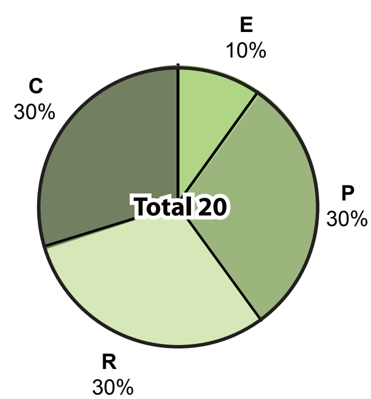




Backcountry Standards







KEY TO ABBREVIATIONS

EN	Environment	**TF**	Team Fitness
IC	Incident Complex	**PL**	Planning
CR	Contingency Recs	**SU**	Supervision
TS	Team Selection	**COM**	Communication

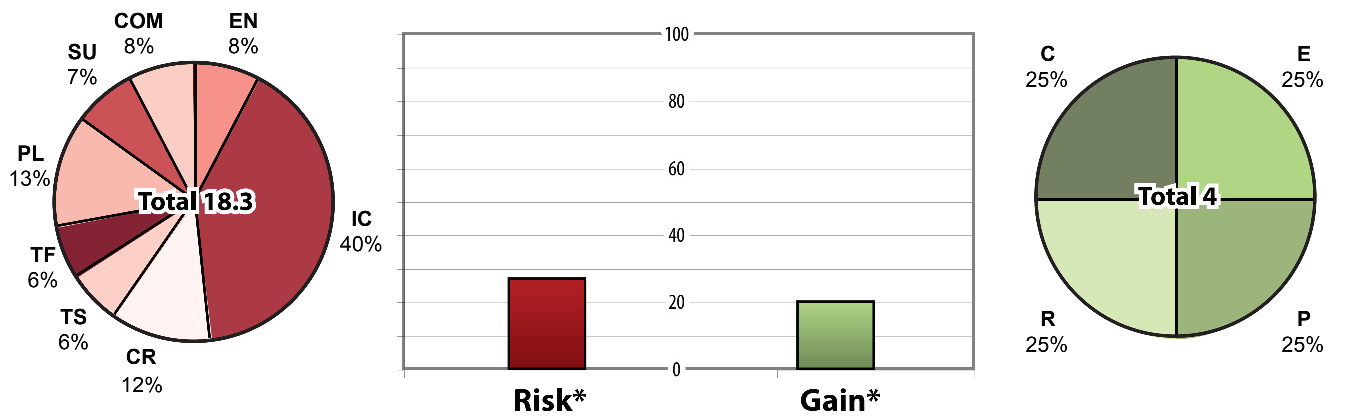
KEY

E	Effectiveness
P	Pass
R	Resources
C	Cost

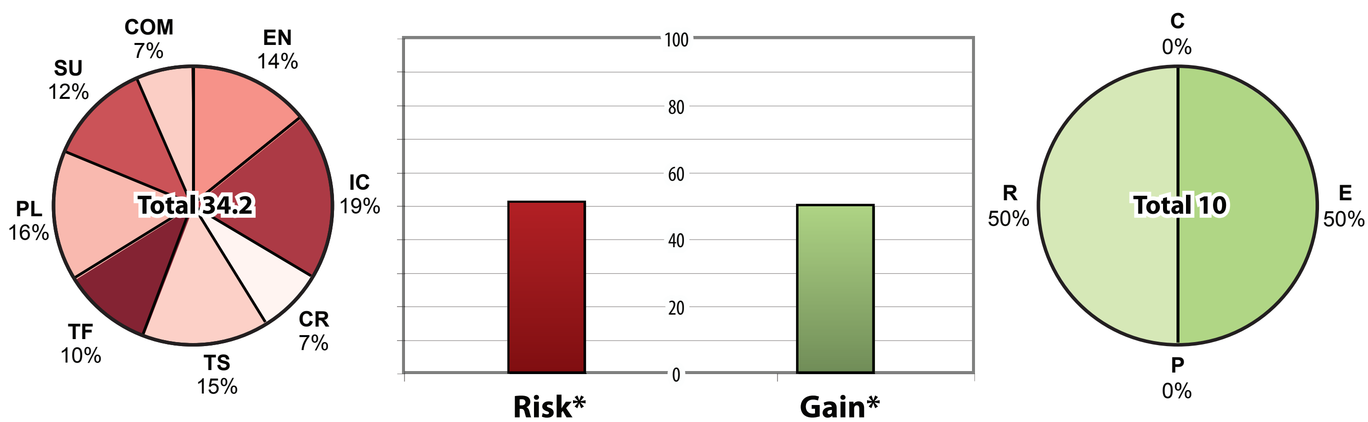
***** The options with the highest Risk and highest Gain are calibrated as equal to 100. Thus Hand Charges Risk = 100 and Backcountry Gain = 100. All other options correspond to these calibrations.

Chart 5. Risk-Gain Ratios

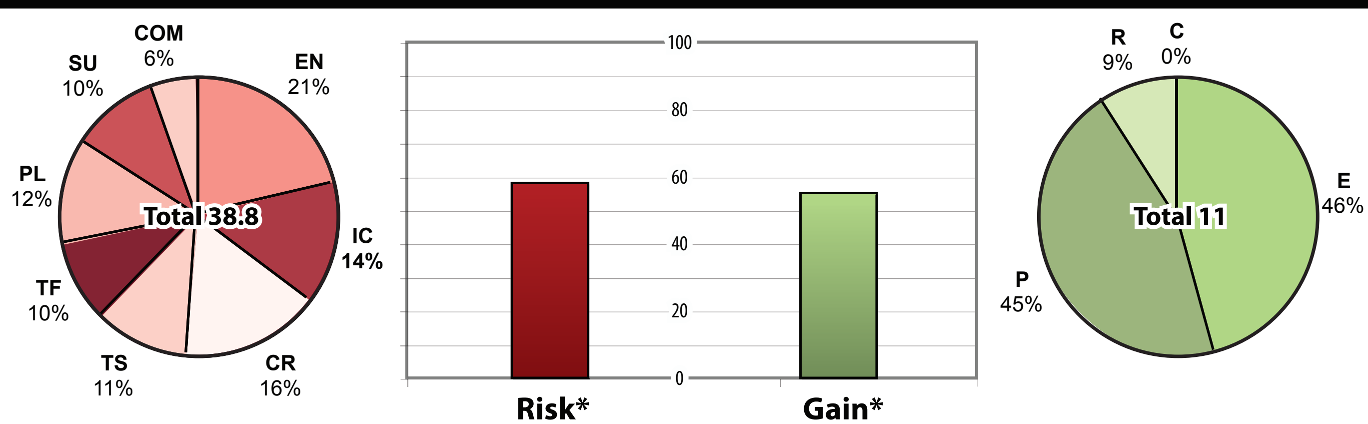
Berms, Deflectors, Catchment Basins



Closure + Helo



Fixed Gas + Helo



KEY TO ABBREVIATIONS			
EN	Environment	**TF**	Team Fitness
IC	Incident Complex	**PL**	Planning
CR	Contingency Recs	**SU**	Supervision
TS	Team Selection	**COM**	Communication

KEY	
E	Effectiveness
P	Pass
R	Resources
C	Cost

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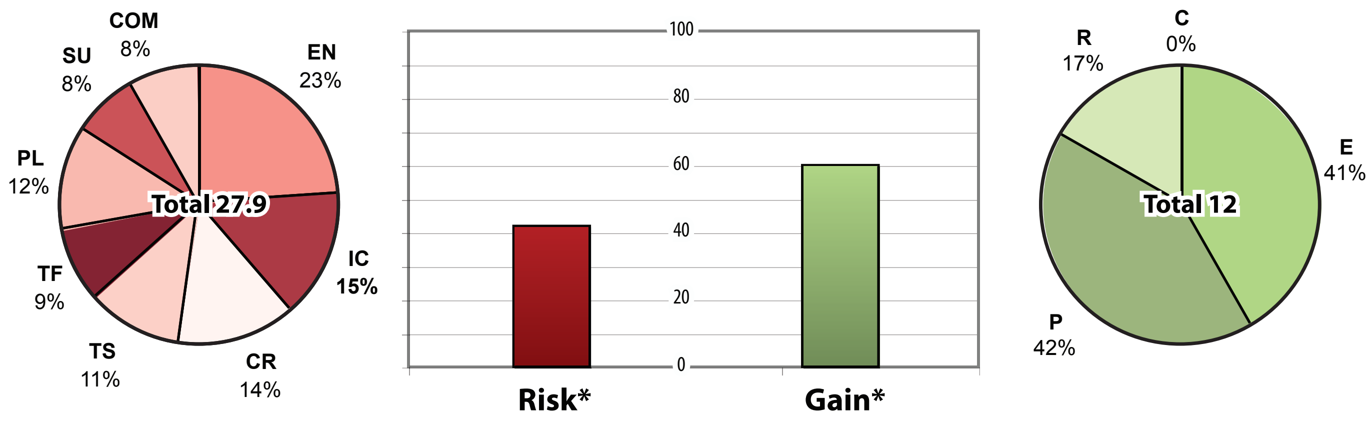
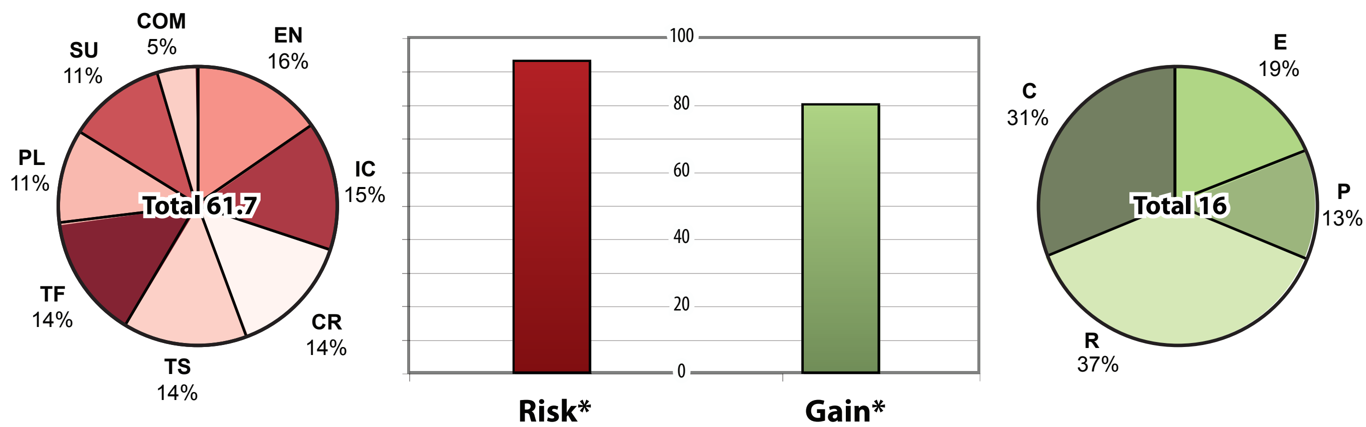
Chart 5. Risk-Gain Ratios

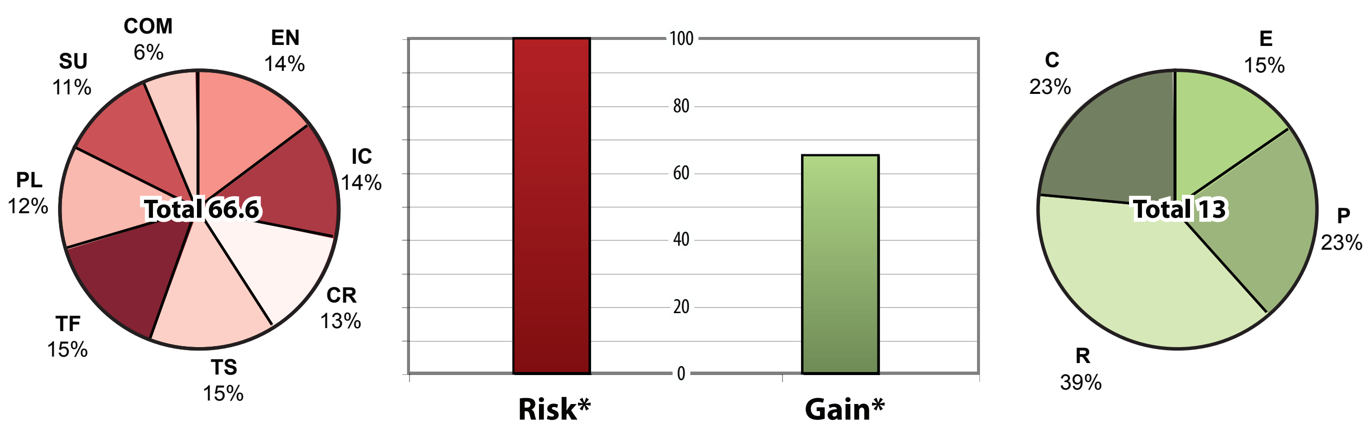
Fixed Gas Systems



Full Forecasting



Hand Charges



KEY TO ABBREVIATIONS

EN	Environment	**TF**	Team Fitness
IC	Incident Complex	**PL**	Planning
CR	Contingency Recs	**SU**	Supervision
TS	Team Selection	**COM**	Communication

KEY

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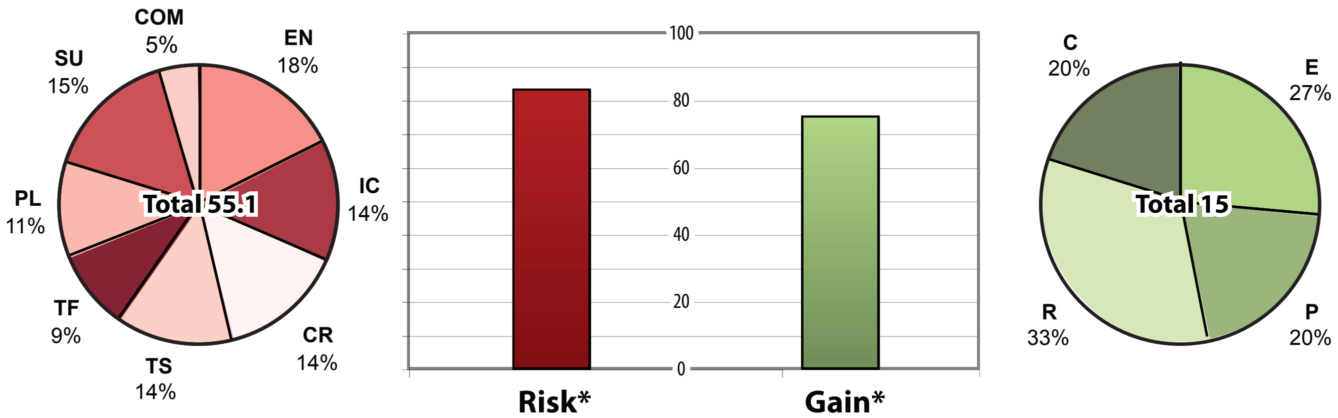
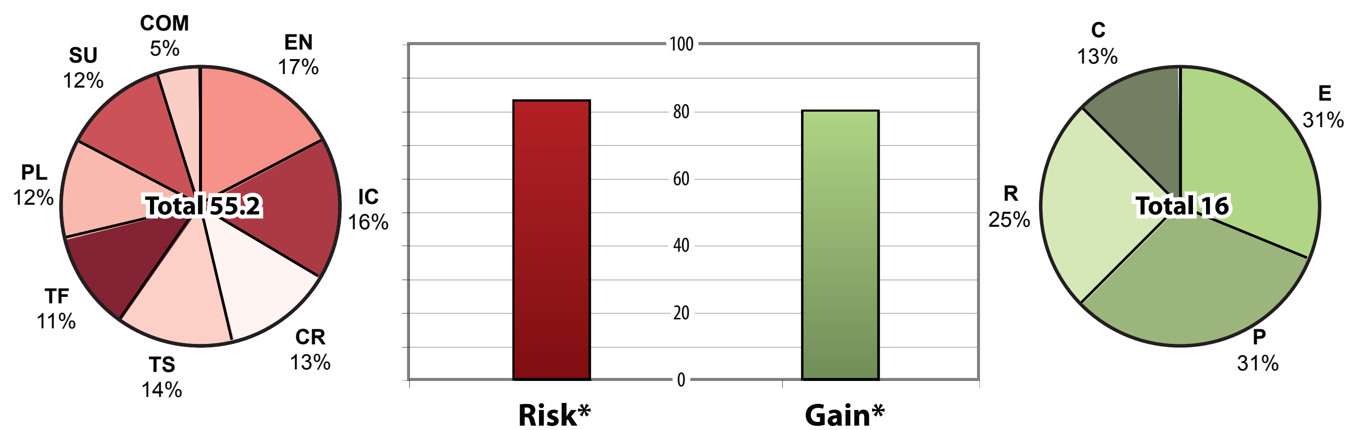
Chart 5. Risk-Gain Ratios

Helicopter



Helo Howitzer



Howitzer + Access Mitigation

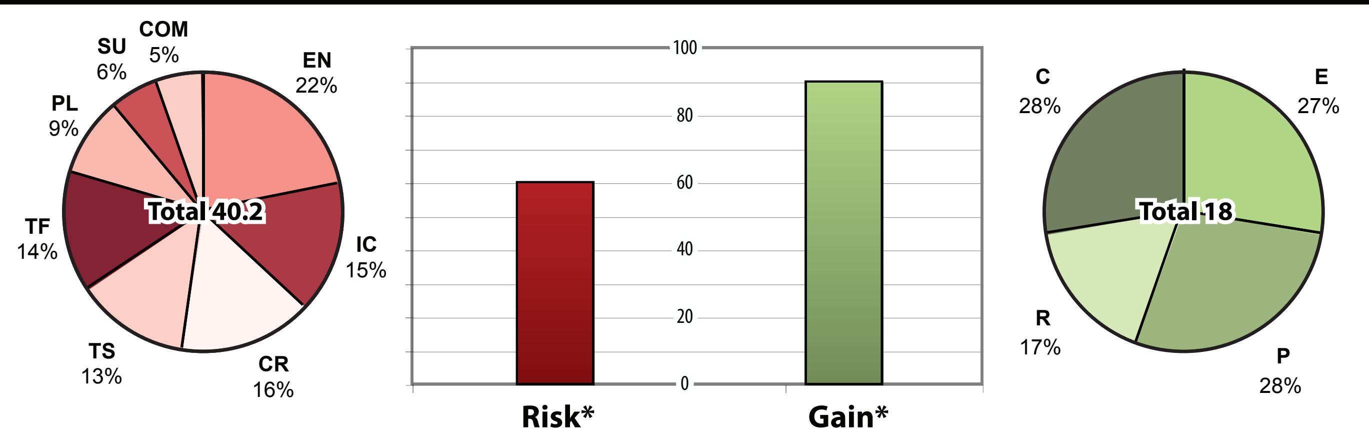


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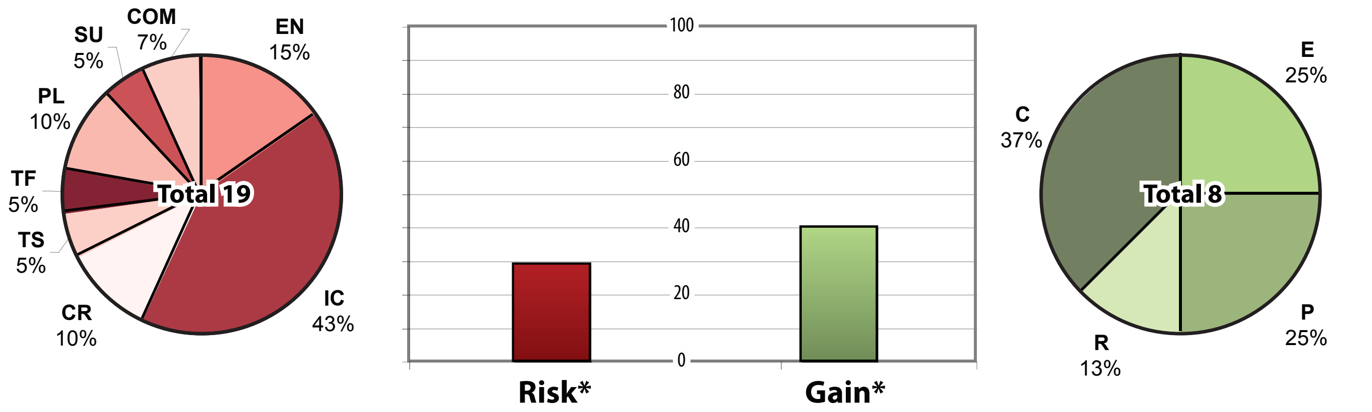
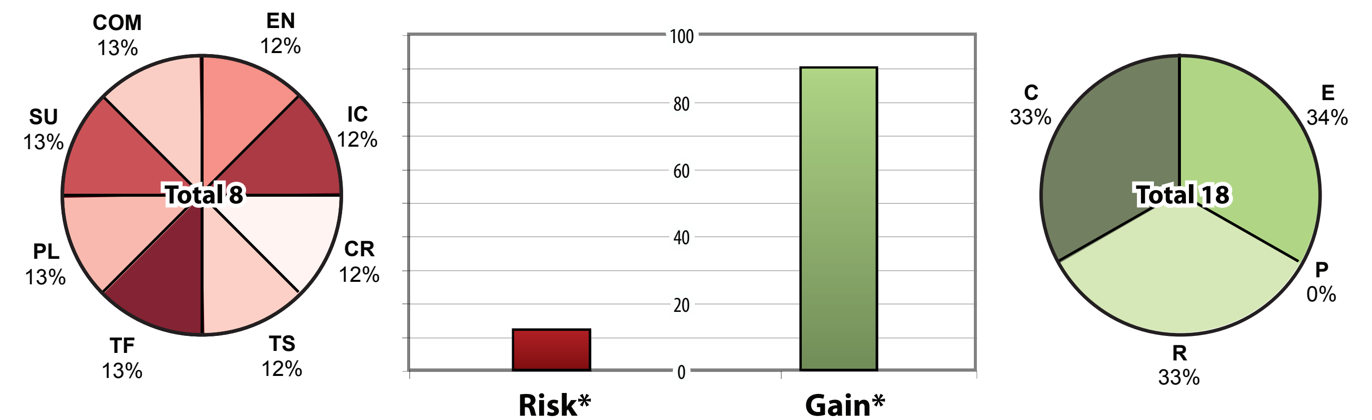
Chart 5. Risk-Gain Ratios

Snow Sails



Total Closure



Trolley/Tram

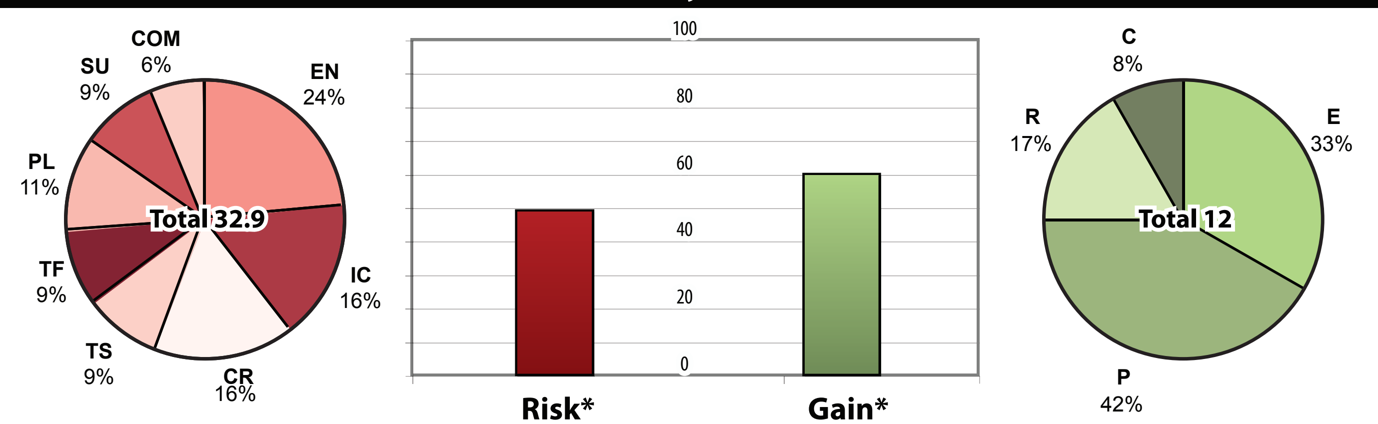


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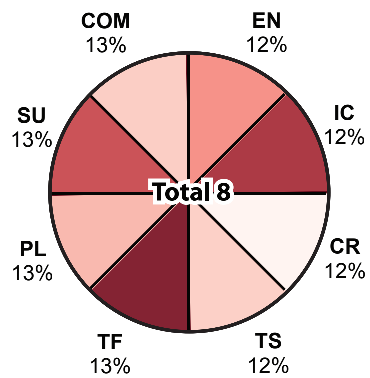
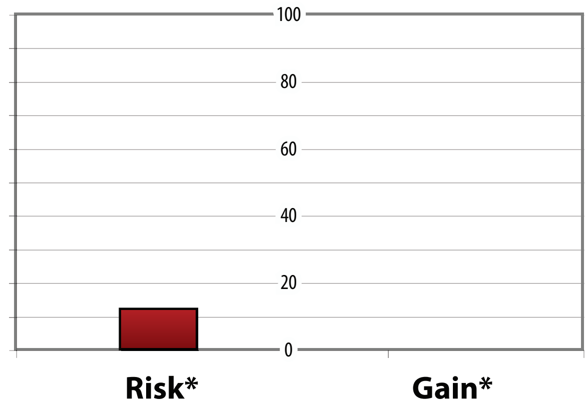
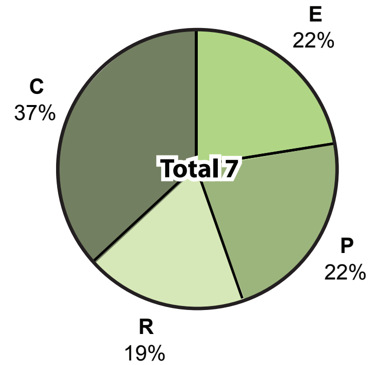
Chart 5. Risk-Gain Ratios

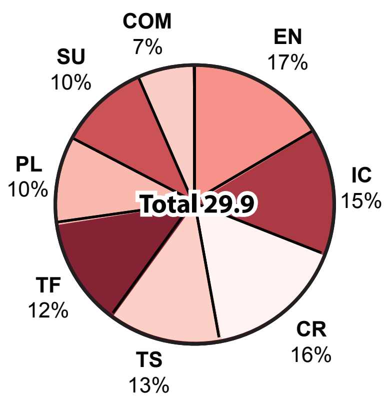
Tunnel/Shed

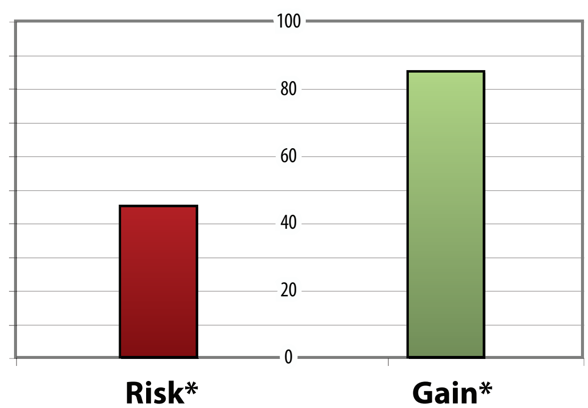


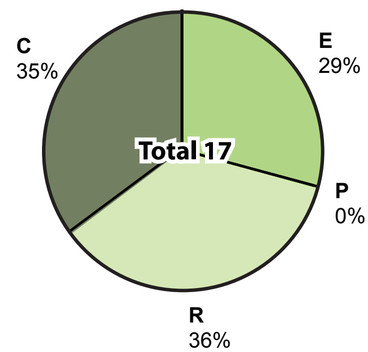




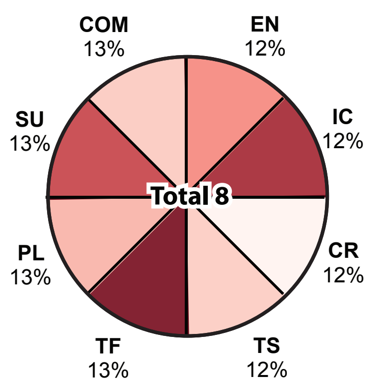
Window Closure

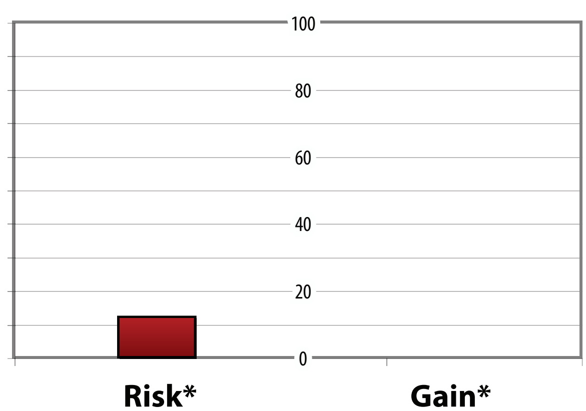


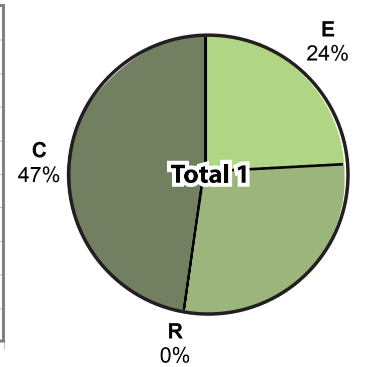




Support Structures in Start Zone







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